

GRIDMAN: A GRID MANIPULATION SYSTEM

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INTRODUCTION

GridMan is an interactive grid manipulation system. It operates on grids to produce new grids which conform to user demands. The input grids are not constrained to come from any particular source. They may be generated by algebraic methods, elliptic methods, hyperbolic methods, parabolic methods, or some combination of methods. The methods are included in the various available structured grid generation codes. These codes perform the basic assembly function for the various elements of the initial grid. For block structured grids, the assembly can be quite complex due to a large number of block corners, edges, and faces for which various connections and orientations must be properly identified. The grid generation codes are distinguished among themselves by their balance between interactive and automatic actions and by their modest variations in control. The basic form of **GridMan** provides a much more substantial level of grid control and will take its input from any of the structured grid generation codes. The communication link to the outside codes is a data file which contains the grid or section of grid.

The grid, whether imported or not, is like a sculptor's clay and the **GridMan** user is like the sculptor who employs his tools to transform his clay into a masterpiece. Like the actions of the sculptor, the manipulations are dynamic. They appear visually as real time grid deformations that occur in dynamic response to local grid controls. As the user interactively applies the controls in various regions, the grid alterations successively and dynamically change the character and shape of the grid.

The typical grid alterations include the injection or removal of pointwise **clusters**, the **angle changes** between coordinate curves, and the free-form **geometric modeling** of region boundaries. In the **geometric modeling**, the actual bodies in the field are changed to accommodate variations in the design. Since the grid format does not change, successive numerical simulations can be set up rather quickly to show the effects of altered body geometry. The pointwise **clusters** are usually injected at sections along boundaries where attached boundary layers are expected and are removed in regions away from bodies where clustering is not needed and is wasteful. More generally, the clusters can be placed at any desired location in the field so that a user can, for example, interactively adapt the grid to the results of a previous simulation in order to gain accuracy in a subsequent simulation. The **angle changes** are primarily applied at the boundaries to produce coordinate orthogonality. As with the clustering, the creation of grid orthogonality is not restricted to the boundary locations. It can be established at any location.

VERSION SB3000

Version **sb3000** is the basic system which operates on **single block three dimensional grids** regardless of the source of blocks. In a very direct sense, it can be applied to a multiblock grid in a **roving** manner whereby a block section can be taken,

operated upon, and then returned to its original place. The block section can be a whole block, a sub-block, or can cut across a number of distinct blocks.

The three coordinate directions in the block are identified by the colors red, green, and blue. The local controls appear in the form of a sparse control net which is distinguished by the color yellow, by fatter lines than appear in the grid, and by a spacing discontinuity adjacent to the boundaries. The number of control points in the red, green, and blue directions are chosen by the user and are determined by how much control the user wishes to exercise. While the decision does not depend upon the number of grid points, it is assumed to be much less in number for each direction.

With the grid block placed in the transitional data file, the user calls **GridMan** into action. He is then prompted to choose the type of session among the possibilities of demonstration cases, restarts, or new grid files. Once the choice is made, the next prompt is to specify the number of control points for the three directions. After those numbers are given, the **GridMan** window comes into view. The window is carved into two primary spaces. The left hand side is the largest sector and is occupied by the three-dimensional image of the grid, control net, and block frame. The right hand side is a strip that contains a header identifying the program name below which are various combinations of graphic buttons.

The Buttons

The buttons represent the various actions for changing the view of the three dimensional object, altering the sections of the volume to be seen, selecting a control point for motion, determining which type of motion, asking for help, and quitting the program. While the buttons are labeled to identify their purpose, that labeling is quite brief due to the allotted screen space. To compensate for this space limitation, as the cursor moves over a button, the header on the strip changes to display a paragraph that gives a full description of the button's function. This process is dynamic and does not require the user to request help or push that button. It merely supplies information which can add clarity should there be some confusion. Its position at the header is sufficiently removed to not be disturbing to an experienced user who does not need such dynamic help. To push a button, the user pushes down and releases the left mouse key. In response, the button graphic displays a depressed key. A repeat click on the button or other action will turn off its function and the graphic button image will appear as an undepressed key. In this way, the user will immediately know the status of which functions are on and off.

The Scroll Bar

When a button is pushed for a change of view or a control point motion, a scroll bar is activated. The scroll bar appears below the three dimensional object on the left hand portion of the window. Upon the push of a button, the title on the scroll bar changes to reflect the mode indicated by the button. When the cursor is brought onto the scroll bar itself, the scroll bar title disappears and is replaced by a ruler that is numbered. The numbers appear at each end to define the range and at the current ruler location indicated by a red vertical arrow that points upward. By placing the cursor on top of the arrow, it can be dragged to a new location on the ruler. The drag is executed by depressing the left mouse key, rolling the mouse until the arrow is at the desired ruler location, and then undepressing the left mouse key. The result of the action appears as soon as the mouse key is undepressed.

While the dragging of the vertical arrow represents a discrete response, a continuous response is available by using the small buttons which appear at each end of the scroll bar. The innermost buttons are labeled by triangles that point away from the bar in their respective positive and negative directions. By depressing one of these buttons, there is a continuous motion in the corresponding positive or negative direction. This motion is seen in the scroll bar by the continuously changing position of the vertical arrow. The smoothly changing values from the scroll bar are fed to the program to perform the smooth changes that correspond to the currently chosen operation. This motion is stopped when the scroll bar button is released. The speed of the operation can also be changed to accommodate distinct needs. A fast motion may first be desired to get points or views quickly into some sort of general position and then be followed by a slower motion to more accurately alter such position. This option for speed adjustment is offered by the outermost buttons on the scroll bar. Successive clicks on the left outermost button will successively slow down the motion. The slow down is indicated by a down arrow on the button. Likewise, the right outermost button is labeled with an up arrow and will cause an increase in speed with each click.

While the scroll bar offers both discrete and continuous motion with speed control, the range of its operation has been given by a ruler of a specified initial length. This length can also be changed by using the middle buttons of the set of three which appear on each end of the scroll bar. The other two have been seen to define the continuous motion and its speed. The middle button on the left is labeled by two triangles that point towards themselves. Successive clicks on it will shrink the ruler length. Likewise, the middle button on the right hand side will expand the ruler length. It is labeled with two triangles that point away from each other.

The Three Dimensional Display

The three-dimensional display consists of up to four constitutive elements. These are (1) the Cartesian x, y, and z axes of the world space, (2) the grid block frame which shows the block edges, (3) the grid, and (4) the control net. The top three buttons allow the user to display any combination of grid, net and frame. The flexibility offered here is that one can simultaneously view these three items to take note of the relative positions of each or can remove some of them to more clearly inspect a particular part of interest.

The Cartesian x, y, and z axes provide the frame of reference for changes in view. They define the space in which the object of our actions is being taken. The block frame gives a view of the entire block volume in a manner which does not obstruct the view of the current elements within that volume. The frame is built up from the edges of the grid block. Aside from the edges themselves, a plot of the boundary grid points adjacent to those edges can appear. These points are connected to their corresponding edge points and to each other in their successive order. In addition, there is a meaning to their appearance or non-appearance. When the first layer of grid on a face is in view, **GridMan** considers that boundary to be specified on a grid point by grid point basis. Otherwise, when only the face edges appear, **GridMan** generates the face from the corresponding sheet of boundary control points. For this selection, there is a toggle button (entitled **Toggle boundary Form**) to switch between the specified boundary and the one which is opened for free-form manipulation. There is also a toggle button entitled **Frame** to switch on and off the display of the frame and world space axis combination.

The grid is displayed by the graph of one sheet at a time. This appears in the chosen color code. In particular, a constant value in the red direction is plotted as a red coordinate sheet; a constant value of green, a green sheet; and a constant value of blue, a blue sheet.

The view of the grid is toggled on and off with the key entitled **View Grid**. There is also the option to display additional images of the grid sheet that are reflected about the origin in the respective Cartesian world space directions. The mirror images are activated by the three toggle buttons entitled **Mirror X**, **Y**, and **Z**. These appear immediately below **View Grid**. In addition, there is a button entitled **Smooth** which smooths the grid lines to remove the stair case effect of plotting lines that are not aligned with the rows or columns of pixels on the screen. A final grid display button is provided to examine the grid surface for its geometric features. It is entitled **Render** and shows the grid surface as a solidly colored object under light sources. The **L** key on the key board returns the user to the previous mode.

Like the grid, the control net is displayed by a graph of one sheet at a time. That sheet appears with fatter lines and is displayed in the color yellow. Since the the actions are executed by control point movements, it is important to also display the effect of such motion relative to the current net sheet. A control point is identified within a sheet by the intersection of the two other net sheets. The intersection is identified by a change from the color yellow to that of the intersecting sheet direction and by still even fatter lines. For example, if the current net sheet corresponds to the grids plotted in blue, then the intersecting ones are represented in red and green respectively. Thus, the red intersection appears in red and the green in green. In addition, this intersection represents a point on a control net curve that intersects the current net sheet. To witness the most immediate effect of a motion without too much screen clutter, this net curve is plotted only up to the first control net point on either side of the current net. On the boundaries, there is only one side for this plot while in the interior there are two. It is distinguished by the color turquoise. The net sheet display is toggled on and off by the button entitled **Net**. Unlike the grid, the net is not given the mirror or render option. Because of the fatness of the lines, the smoothing option is not needed.

The last display button is entitled **Depth**. It is used to clarify graphically which part of an object is in front of another object or part of an object. This is necessary to see items as they naturally appear in three-dimensions. Otherwise, something in the inside could be plotted over something on the outside. This operation is known as depth queuing and is well known. In the present case of Cartesian axes, the frame, the net, and the grid; the improvements from the depth queuing are modest. With solidly colored objects, the improvement is much more substantial.

Change of View

Given a three-dimensional object in the display, the position from which it is viewed may not be appropriate and must be changed for a better inspection. This is accomplished with the buttons under the subheading **Change View**. The basic rigid body motions are attached to the world space coordinate axes. The respective rotations are about the point center of mass of the entire grid block. This is computed in a pointwise rather than volumetric sense so that the emphasis is given to the point densities that are viewed. The center components are then just the separate averages over the total number of block points in the respective x, y and z directions. The rotations appear as a row of three buttons entitled **Rotate X**, **Y**, and **Z**. The respective translations are given by the next row of three which are entitled **Transl X**, **Y**, and **Z**. Relative to the point center of mass, the graphic image can be expanded or contracted with a zooming operation. The operation is activated with the **Zoom** button. Once activated for rotate, translate, or zoom, the scroll bar is dynamically labeled to reflect the choice. The user then moves the cursor to the scroll bar and performs the labeled task. As mentioned in the scroll bar discussion, there are the

options for continuous motion with adjustable speed and range as well as the discrete motion by use of the ruler position arrow.

While the center of gravity position generally keeps the graphic object in view for the rotate and zoom operations, the zoom to inspect a particular part of the grid may fall off of the screen. This would then require the user to apply a translate to bring it back into view. Rather than be forced into this situation, an alternative operation is offered. The operation is entitled **Focus**. When the **Focus** button is pushed, the user brings the cursor to a position on the screen, depresses the left mouse key, drags the cursor in a diagonal manner, and releases the mouse key. This dynamically puts a rectangular box in screen space about the region to be expanded. When the left mouse button is released, the expanded image appears. While such expansions can be done any number of times in succession, there is an undo command that allows the user to step back up to eight times. Beyond eight, the previous stages are not stored. Each step back to a previous stage is accomplished by clicking on the **Un-do** button. The last button is entitled **Reset Graphics** and brings back the original view of the object from the very beginning of the session.

The Selection of Net and Grid Sheet Displays

The display of the net and grid is given by sheets that can be seen in detail without the clutter that results should a three dimensional volume be displayed. The sheets are just the coordinate or natural net surfaces that are given by holding fixed one of the three curvilinear coordinates. The three dimensional volumetric view then comes from the dynamics of shifting through the collection of sheets.

The motion of the net sheet is given by pressing the key entitled **Scroll Net Sheet**. With each click of this button, the net sheet is scrolled in the current direction in the current plus or minus orientation. This scrolling action will go up to a boundary, will go to the opposite boundary, and will continue back towards the first boundary. Along with the scroll of the net, the grid display will also scroll should it be in view. This occurs because **GridMan** automatically chooses to display the closest grid sheet in the same direction. This automatic selection is made because the grid sheet closest to the net reflects most closely the character of the net as compared to sheets that are further away. Thus, when a control point is to be moved, its major effect on the grid can be witnessed most directly in a dynamic manner.

To change directions or the orientation in a given direction, there is a row of buttons just below the **Scroll Net Sheet** button. These are labeled **I**, **J**, **K**, and **+/-**. In keeping with the red, green, blue convention there is a one-to-one correspondence of (I, J, K) with (red, green, blue). In fact, the **I** appears in red; the **J**, in green; and the **K**, in blue. As an alternative, the scroll in the current direction can also be executed with the **I**, **J**, or **K** button with the same color as the grid display should it be present. When the color is different, the sheet is flipped into one with the color of the pressed button. The sheet which appears from the flip is the one which passes through the current control point that was highlighted on the previous sheet. That same point is also highlighted on the flipped sheet which indicates that no scrolling action occurred on the press of the given button. Further presses on the same button or on the **Scroll Net Sheet** button will give the scrolling action. This can be continued any number of times. To reverse the orientation the plus/minus button **+/-** must be pressed.

Aside from the grid display as it appears in the scroll of the control net, there is a separate means to view it. This is important so that a user can view the entire volume of the

grid. This is accomplished with the press of the button entitled **Scroll Grid Sheet**. Once pressed, the scroll bar is labeled accordingly and the user then moves the cursor to the scroll bar to perform the operation. With this operation, the grid sheets in the current direction are scrolled from the original position. The motion is either discrete or continuous. In the continuous case, the view appears in a dynamic form like a movie. This temporal approach gives a real feel of how the grid behaves in a volumetric sense. This motion is independent of the net. Should the net be still in view, it will appear statically in its original position. To switch directions, the user must return to the buttons on the right hand side to change the net direction and then to scroll the grid again.

The Selection of a Control Point

A control point is identified by its displayed control net sheet and the highlighted intersection of the two sheets in the directions of the other colors. Within the yellow net sheet, the current control point position is where the two control point curves of different colors intersect. In the case of a blue direction, the displayed grid if it appears is blue and is near the mostly yellow net sheet. In the red direction (constant sheets of red), there is a red net curve through the current control point. Likewise, there is a green net curve in the green direction. The intersection of red and green identifies the current control point. In addition, the current point is identified geometrically with the net curve that extends transversely piercing the sheet. The extent of that curve is limited to connect the net points just above and below the current net point. It appears in a turquoise color.

With the scrolling operation for net sheets, a sheet in which the point lies can be selected. The next operation is to move the highlights to the points that we wish to identify. This is achieved by scrolling within the current net sheet. The action is taken by clicking the buttons which appear under the sub-heading entitled **Choose Control Point**. Again there is a sequence of **I**, **J**, **K**, and **+/-** buttons. Like the previous buttons for the net sheet scrolling, the same functionality and color codes apply. The only distinction is that nothing happens if one presses a button of the same color as the current net sheet direction. This, however, is just common sense because there are only the other two colors left for the scrolling action within the net sheet. That scrolling action is exactly the same as with previous case of the net sheets themselves.

The Motion of a Control Point

Once a desired control net point is identified to be the current net point, there are two options provided for movement. It can be moved within the net sheet surface or along the transverse links to the control points just above and below the net sheet surface.

To move within the net sheet, the button entitled **Move On The Plane** must be pressed. The cursor then appears at the center of the screen and a movement of the mouse will cause a motion of the control point. In effect, the motion of the mouse is mapped into a corresponding motion of the control point in its net surface. Along with this control point motion, the three dimensional grid is dynamically altered. This dynamic is seen as a smooth continuous motion of the grid in real time with the control point. Because the closest grid sheet to the net is in view, the most prominent changes in the grid are seen in this dynamic fashion. To see the effect on the full three dimensional grid, the user must apply the scroll grid sheet options in the various directions. During the movement, there are several options that can be exercised. One is a switch between the quadrants about the original position of the current control point. This is activated by pressing the **right mouse key**. The other option is to adjust the mapping to accommodate an interchange of

the vertical and horizontal motions of the mouse. The is activated by a press of the **center mouse** key. The motion is stopped and control is returned to the button array with a press of the **left mouse** key.

The speed of the motion within the net sheet can be adjusted. The controls appear in the buttons immediately below the one for **Move On The Plane**. To speed up the motion, press the **Fast Moving** button. The intensity of increase is given by the number of times the button is pressed. To slow down the motion, press the **Slow** button a desired number of times for the appropriate intensity. With the adjustments for speed, the next time the user activates the movement in the net sheet, the selected speed of response appears. The speed adjustment is useful to quickly deform the grid into a desired general shape and then to be able to slow it down to permit slower more accurate movements.

The motion along the transverse links that pierce the control net sheet is activated by pressing the key entitled **Move Off The Plane**. Once pressed the scroll bar becomes appropriately labeled and the user moves the cursor to operate the scroll bar. This already contains the speed adjustments. When this motion is occurring the user sees the geometric changes in the nearest surface appear in real time. This is particularly convenient for the case when the boundary is to be deformed.

With the two types of motion, the application to the boundary is special. When it is left in the specified mode, the control point changes have no effect. In order to model the boundary in a free form manner, the strict adherence to the boundary grid must be released. This is accomplished by first moving the current control point to the desired boundary face and then by pressing the toggle button entitled **Toggle Boundary Form**. The toggle is a switch between its rigid specification and its definition in terms of control points. Once in the free-form state, the motion of any control point on that boundary will change it. The user can tell if a boundary face is opened up for free-form manipulation by seeing if the frame graphic does or does not have its fringe of grid points plotted in the first interior layer.

The End of a Session

The session is ended by two quit commands. The first given by the button entitled **Quit Without Save** and the second is given by the button entitled **Save Grid Then Quit**. When the grid is to be saved, the user is queried for a file name.

Utilities

The general utility features are a request for more detailed help and the options to use the key board in certain cases. For example, the **I, J, K** keys operate with the same meaning as the corresponding graphic buttons. The detailed help is activated with the button entitled **CPF Help**. The CPF refers to the technical structure of the algorithm.

THE DYNAMIC MANIPULATION OF GRIDS

As an illustration of how the various active elements of the code are applied, an example session is provided below. This will show the use of the viewing features and the changes of the graphic object. It will allow one to see how one shifts the various parts of the three dimensional display about to show the parts of current interest. With the various configurational steps, the movement actions will be taken. This will demonstrate the various types of control point motion and their effects.

```
aixterm

Single Block Control Point Form of Grid Manipulator and in 3-D by PDC

1). Demonstration.
2). Read in initial grid.
3). Resume previous session.
4). Quit.

==> 2

a). plot3d format.
b). plain format.

==> b

The grid data file should have this format:

grid numbers on one line
loop over all i
loop over all j
loop over all k
loop over x, y, z values.

Enter file name (q to quit) ==> ../../sb3d/nose.dat

Allocating grid memory...

Reading the input grid. Please wait...
```

1. This is basically self-explanatory. You are prompted for different options step by step. For example, at the first input prompt (==>), we choose 2 to read in a grid. At the second prompt, we choose b for plain input format. Then for the third prompt, the file name is entered. Note that since we use dynamic memory allocation, the size of the grid can be as large as your system can take. If you have insufficient memory, however, you should remove the -DMAXMEM option in the *Makefile* and type make again to re-generate *gridman.sb3000*.


```

aixterm

grid numbers on one line
loop over all i
loop over all j
loop over all k
loop over x, y, z values.

Enter file name (q to quit) ===> ../../sb3d/nose.dat

Allocating grid memory...

Reading the input grid. Please wait...

Calculating center of mass...

Shifting the grid to the center of mass coordinate...

The grid indices are from (0 0 0) to (49 49 49):
Type <return> to apply CPF to the whole block;
Type 0 to disable CPF (i.e., viewing the input grid only).
You may also enter a sub-block where CPF would be applied.
Remember CPF requires at least 3 grid points in a direction.
You may also enter, for example, 0 0 5 49 49 5, to apply CPF
only to k = 5 grid sheet for a surface manipulation.

===>

CPF block will be from (0 0 0) to (49 49 49).

Enter control numbers in I, J, K directions.
<return> for the default 1:4 control/grid ratio.
Note in CPF the minimum number of controls in one
direction is 5. If this is a CPF surface, put 0 in
the normal direction.

===>

Control numbers are 12 12 12.

Allocating system memory for CPF...

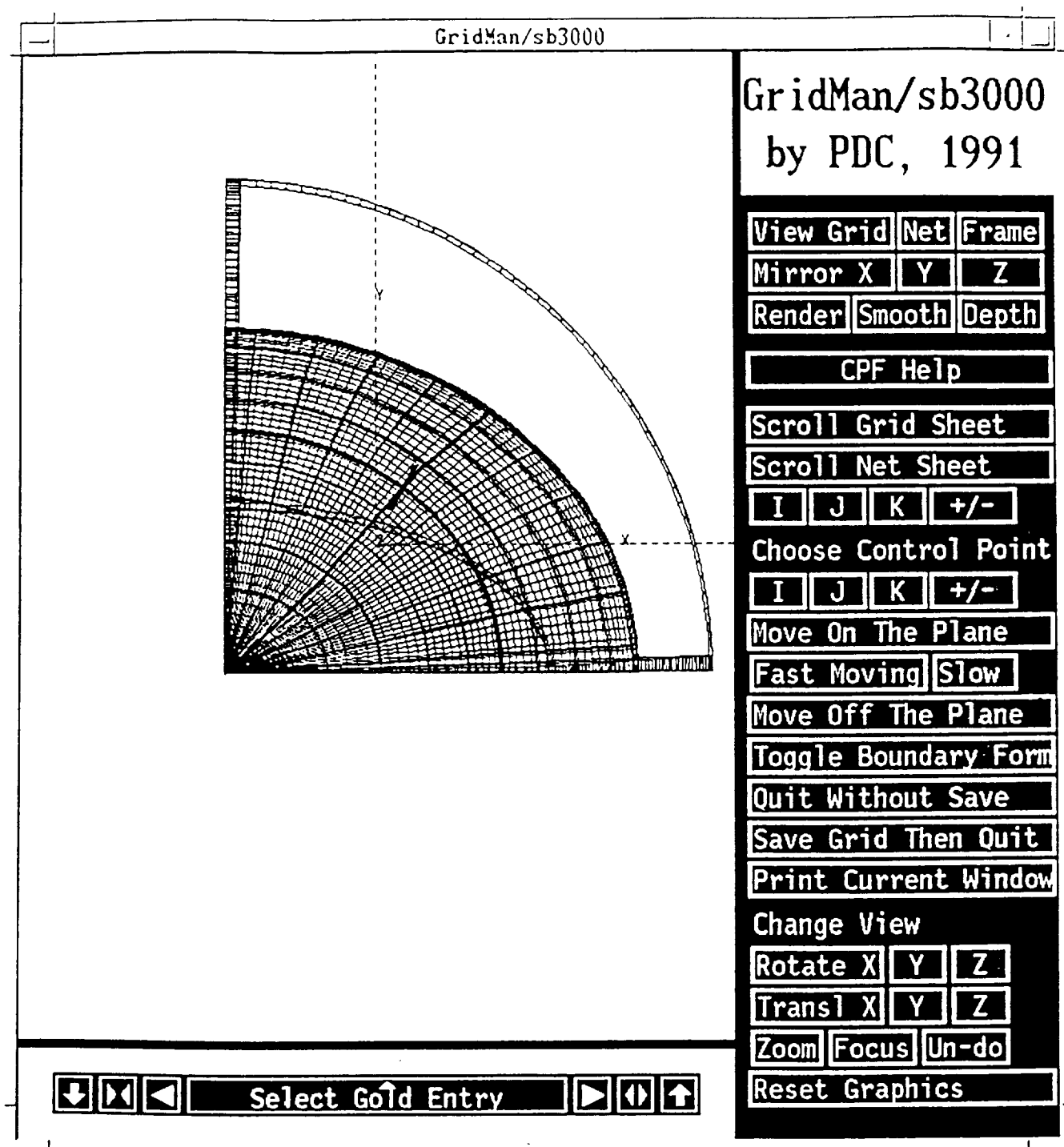
Computing blending functions...

Attaching control net to the grid...

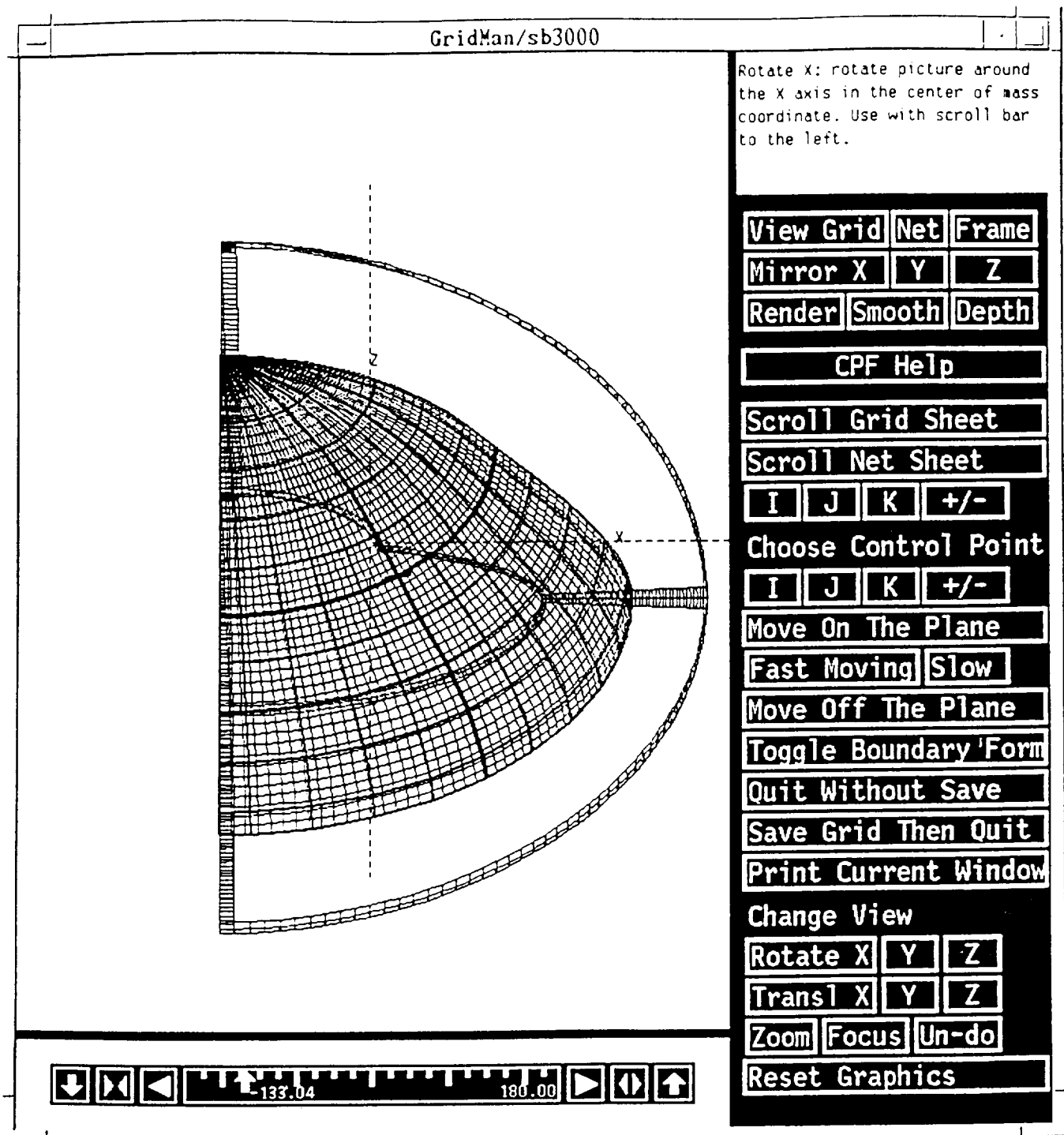
Loading the specific boundaries...

Reconstructing the grid with CPF. Please wait...
```

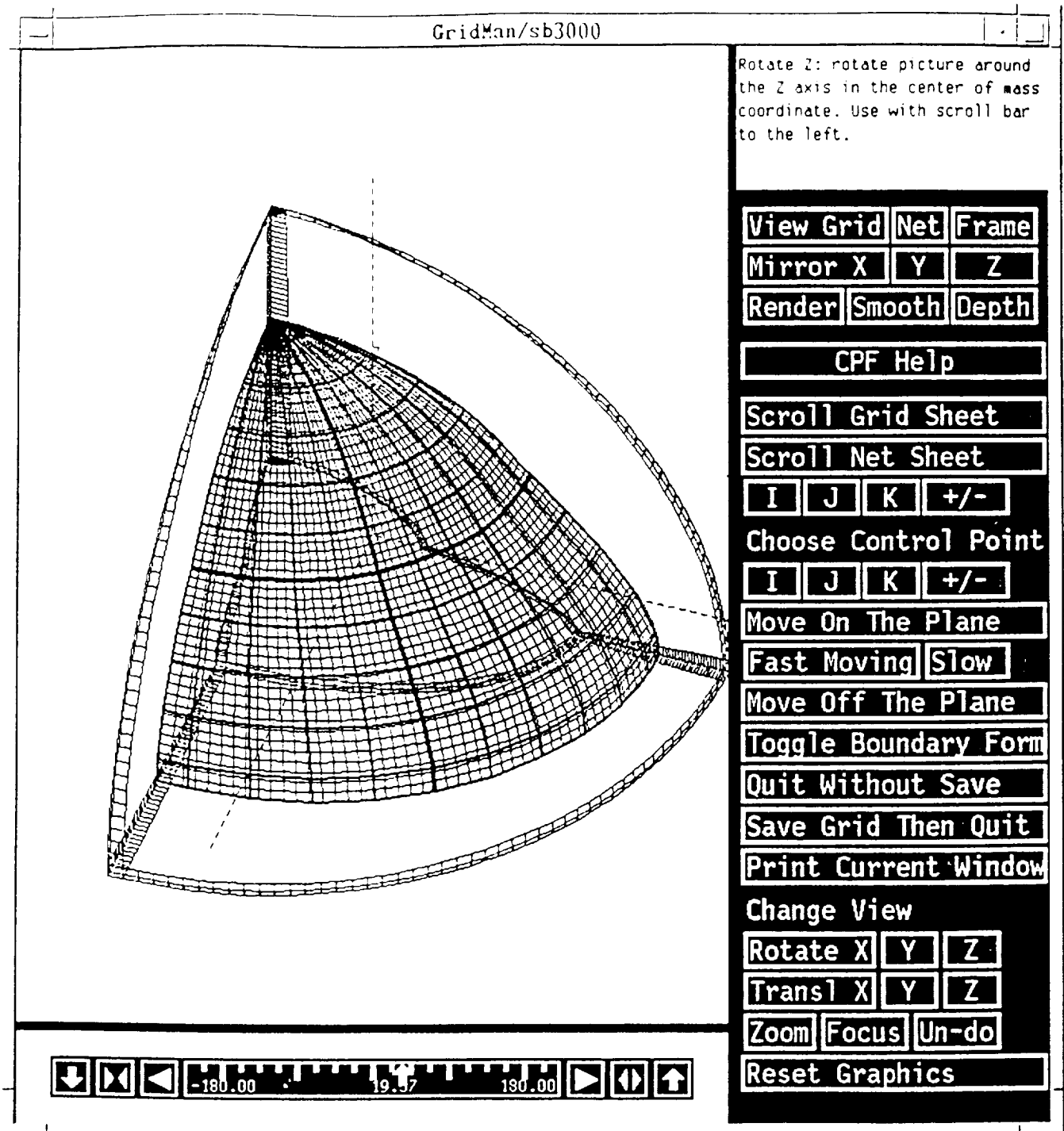
2. The first prompt on this picture is really the third prompt on the previous picture. The second prompt here asks where to apply CPF (Control Point Form). Here we simply type <Enter> to take default action which is to apply CPF to the whole grid block. The third prompt asks for the degrees of control you would like in each direction. The larger the number is, the more local control you have in that direction. Here we use the default action.



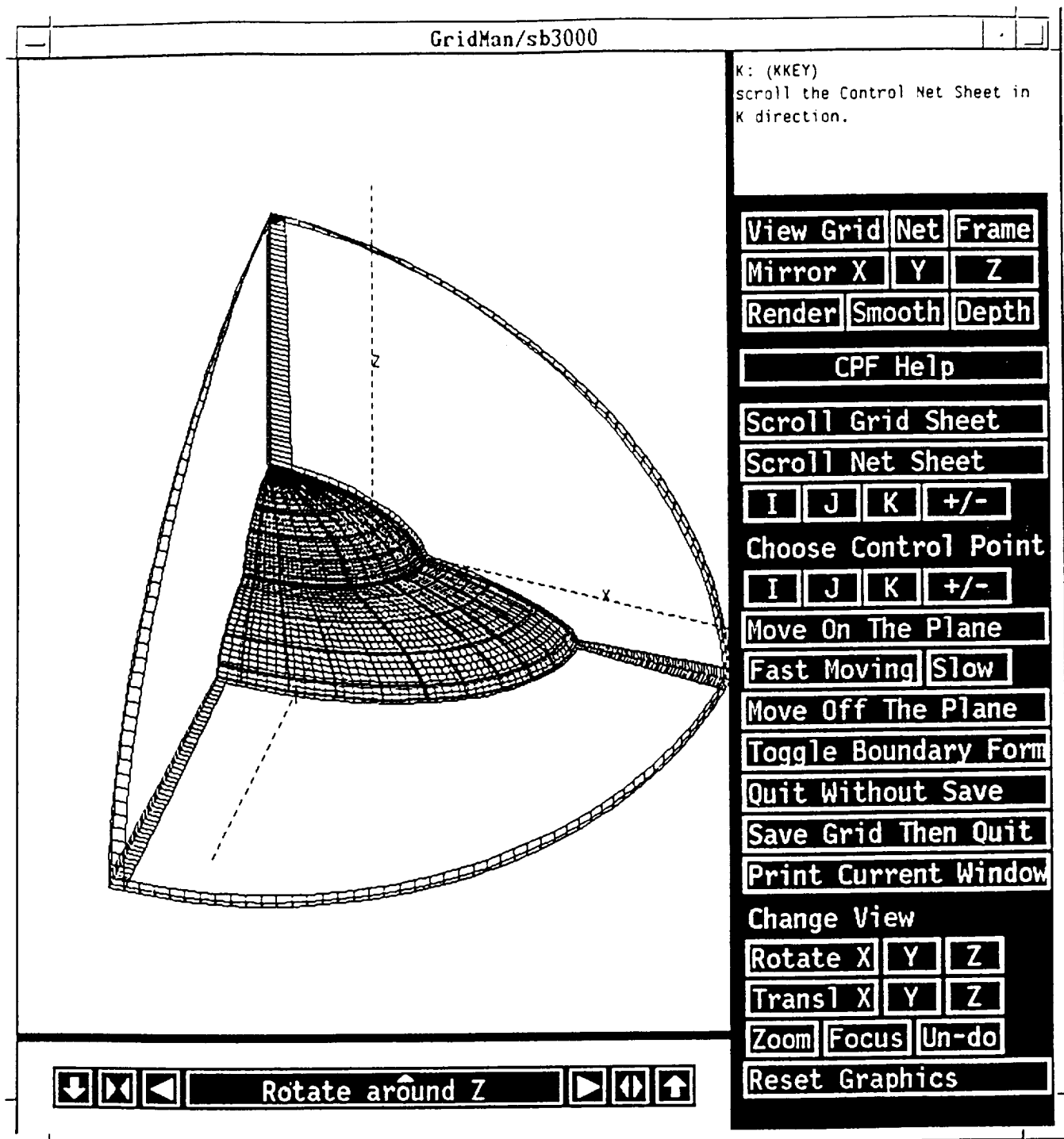
- After a few moments, you will see the graphics display which has mainly three parts: 1). grid and net and frame display; 2). scroll bar; 3). menu bar. You generally use left mouse button to choose from menu bar or to use scroll bar. And some of the menu buttons have their keyboard equivalent. A dynamic help is available whenever a cursor falls on a button. General help is also available via CPF Help button.



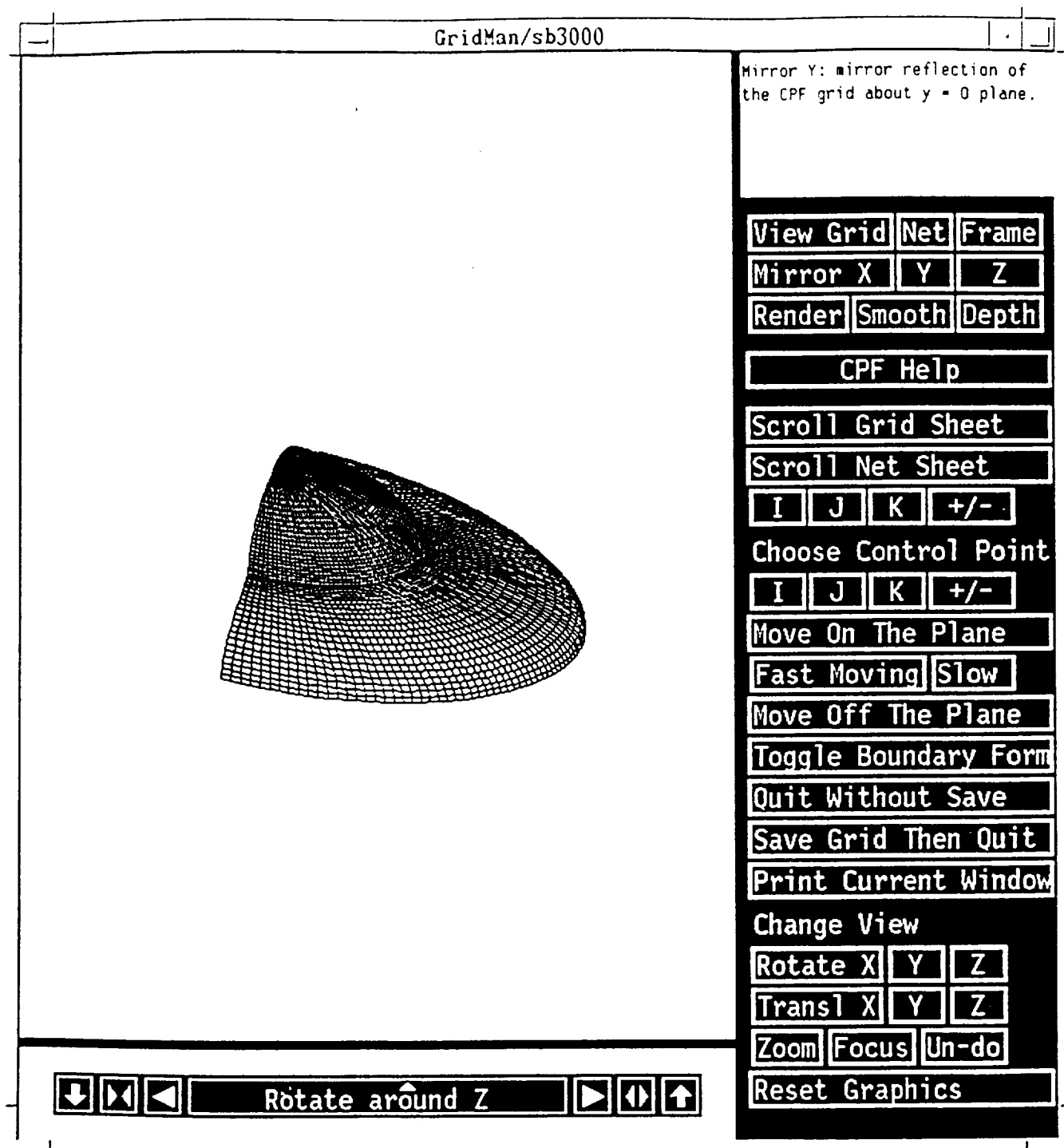
4. We first use modeling commands to get a better view of the graphical objects. Here we use scroll bar to rotate them around X axis. Note that we are using the center of mass coordinate which is the default. To do so, we first click on the Rotate X button, then click and keep pressing the ◀ icon on the scroll bar to continuously rotate around X axis.



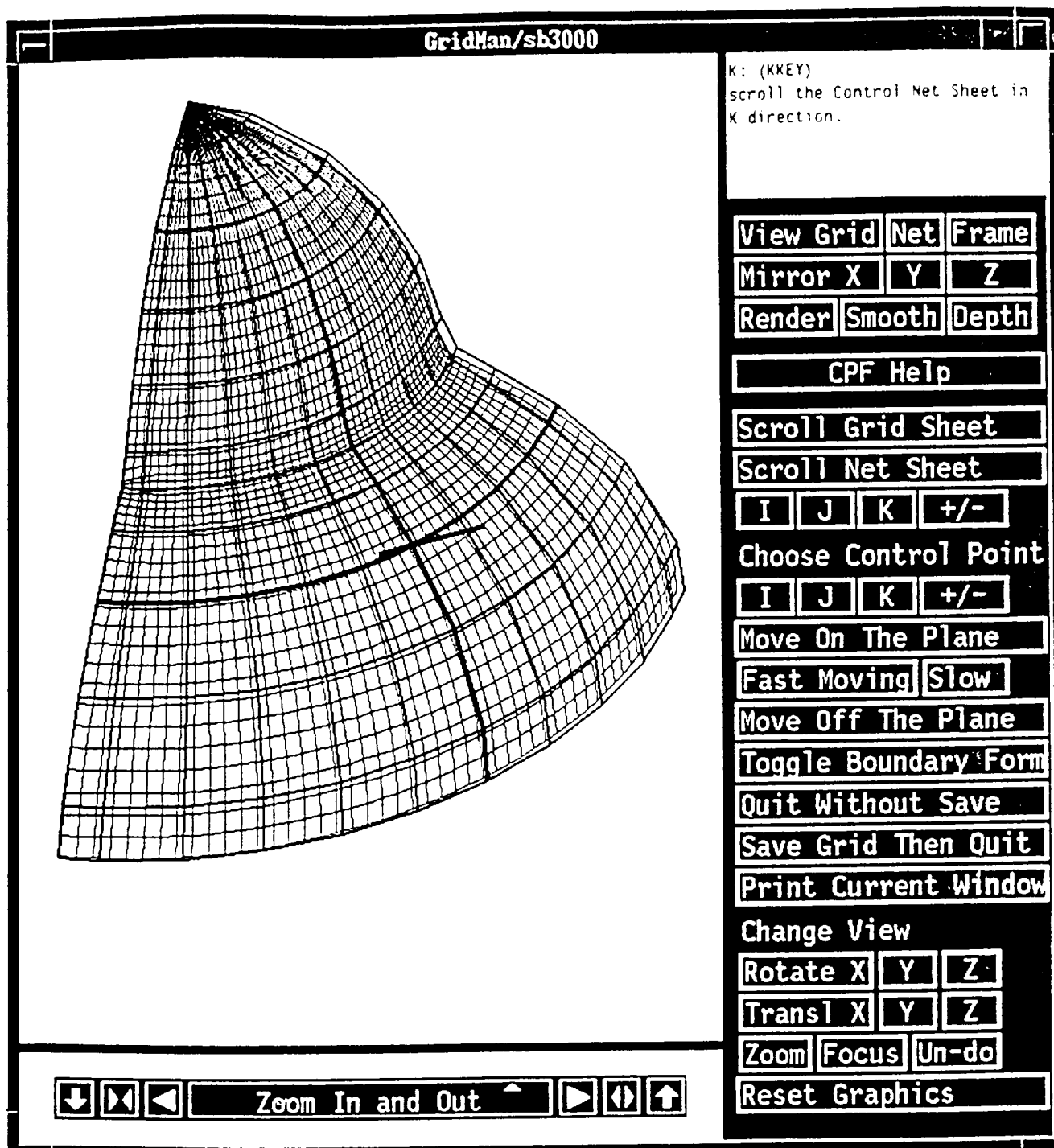
- Now we click on the Z button (next to Rotate X button) followed by ▸ of the scroll bar to rotate about Z-axis. To see which axis is which, refer to the coordinate frame object (you see it clearly on previous page) which has dotted lines for axes and letters X, Y, Z for directions.



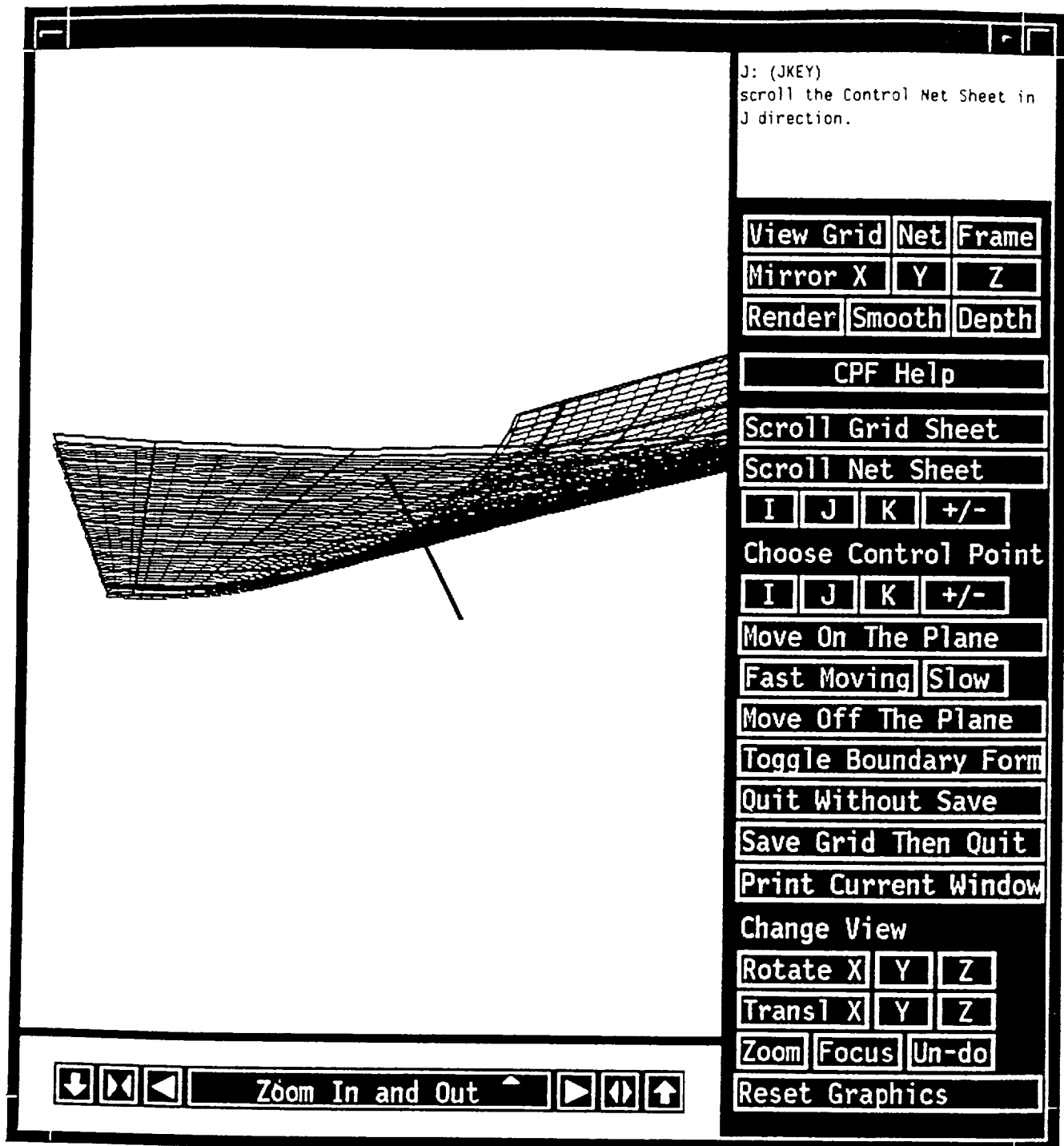
6. The initial grid and net sheets viewed, by default are the middle sheets in K direction. One may be interested in the boundary surfaces in that direction. The simplest way to do that is clicking on **K** button (below **Scroll Net Sheet** button) several times. You will find that when the net sheet is scrolled, the closest grid sheet to the net sheet in that direction is displayed. If you go over, use **+/-** button to reverse scrolling direction.



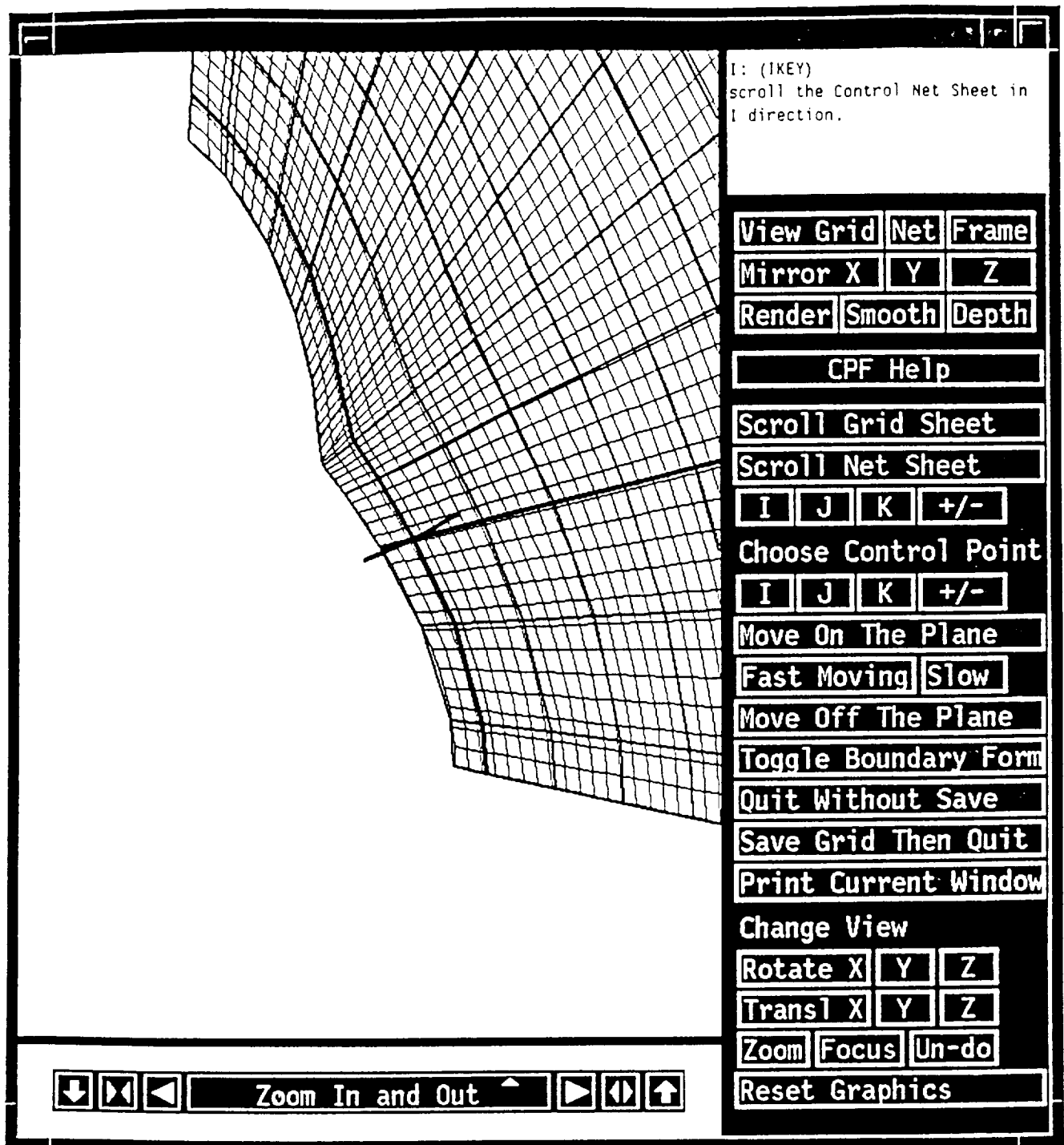
- Now we click on the Net and Frame buttons (next to View Grid button) to toggle off the viewing of net and frame. Also since this particular grid is symmetric in Y direction, one can click on the Y button (next to the Mirror X button) to get a full view of the grid without distraction of the net and the frame.



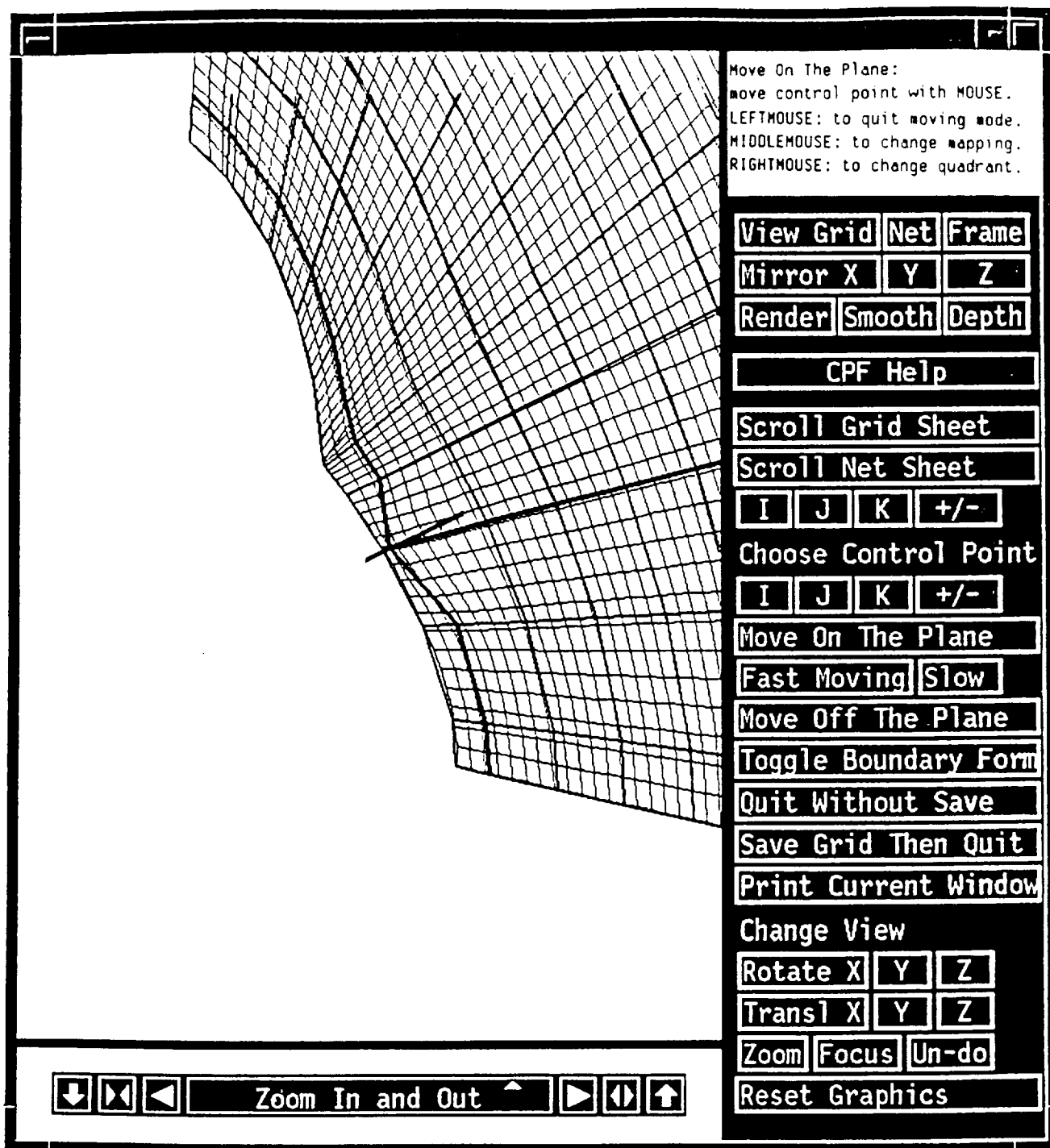
- Now we would like to manipulate the grid with control points. We first use **K** button (below **Scroll Net Sheet** button) a couple of times to move out of the boundary surface just showed, then click on **Net** (next to the **View Grid** button) to put the control net display back on again.



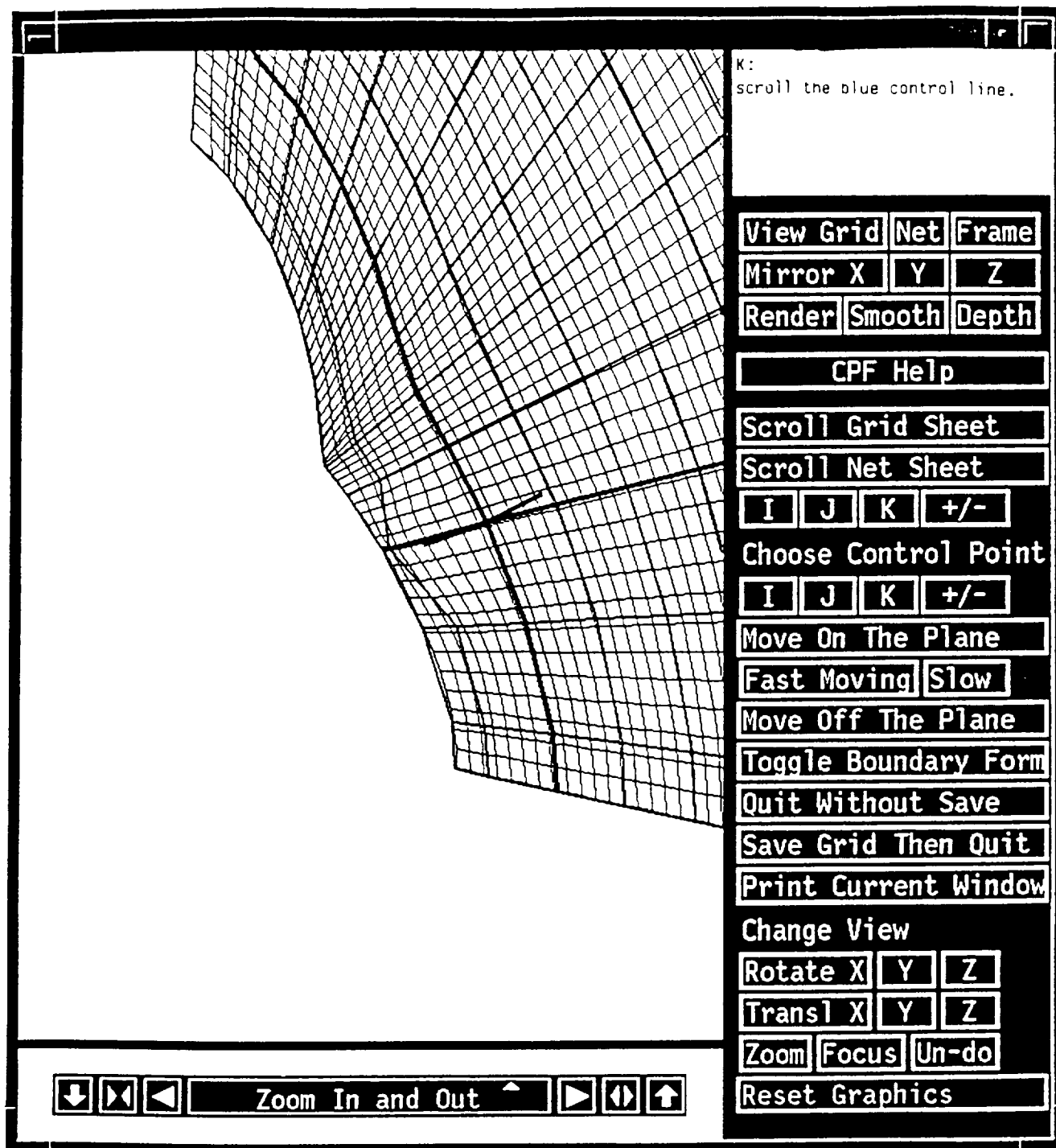
9. By clicking on J button (below Scroll Net Sheet), one gets a view of the net and grid in J direction. The dark line in the middle is the 3-point transverse vector for the current control sheet that can be used to guide Move Off The Plane operation.



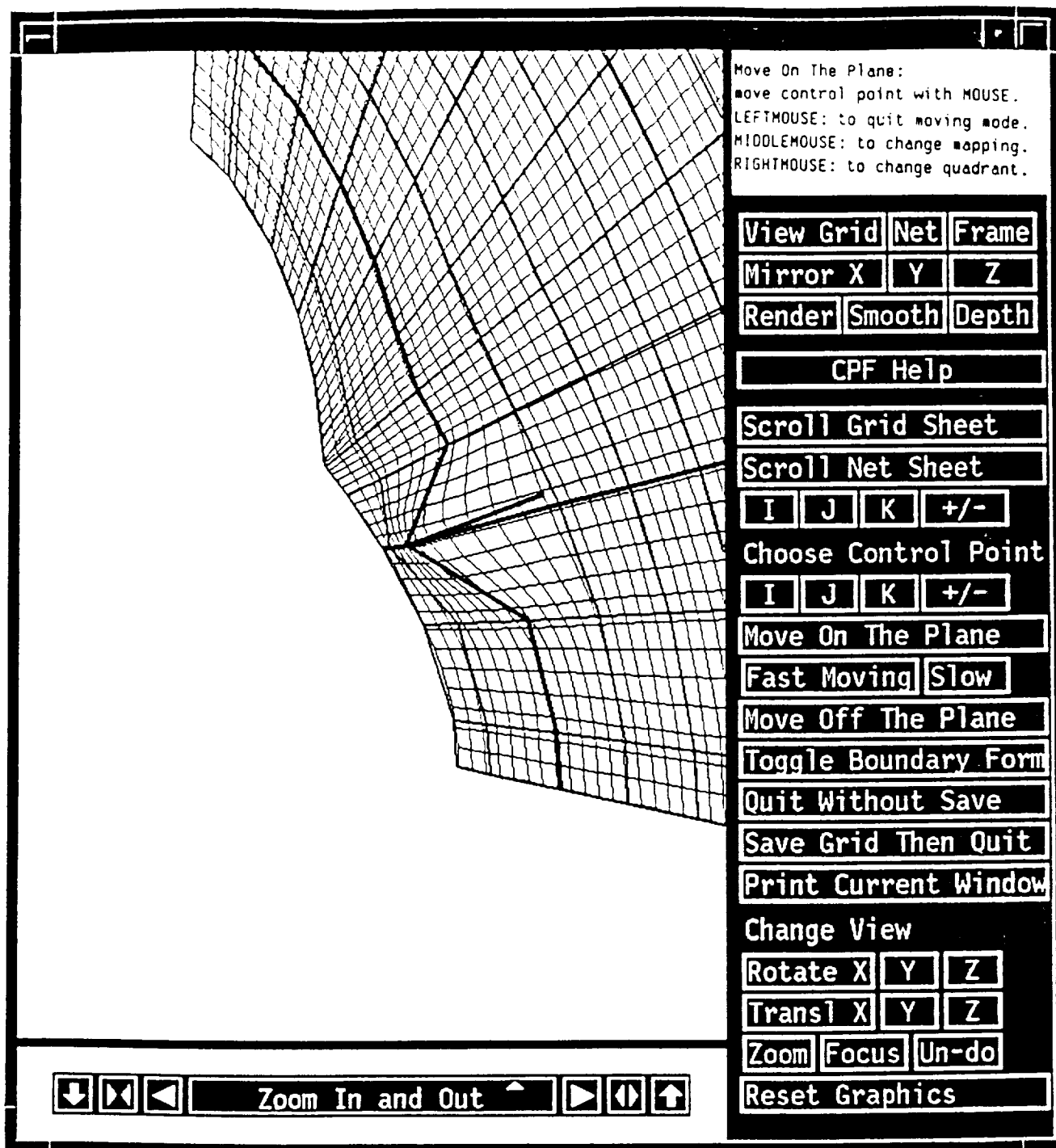
10. Same as above except now we are viewing the objects in I direction. Notice the two thick lines on this plane whose cross point is where the transverse line goes through. This is the control point we can dynamically move, either by Move On the Plane or Move off the Plane button.



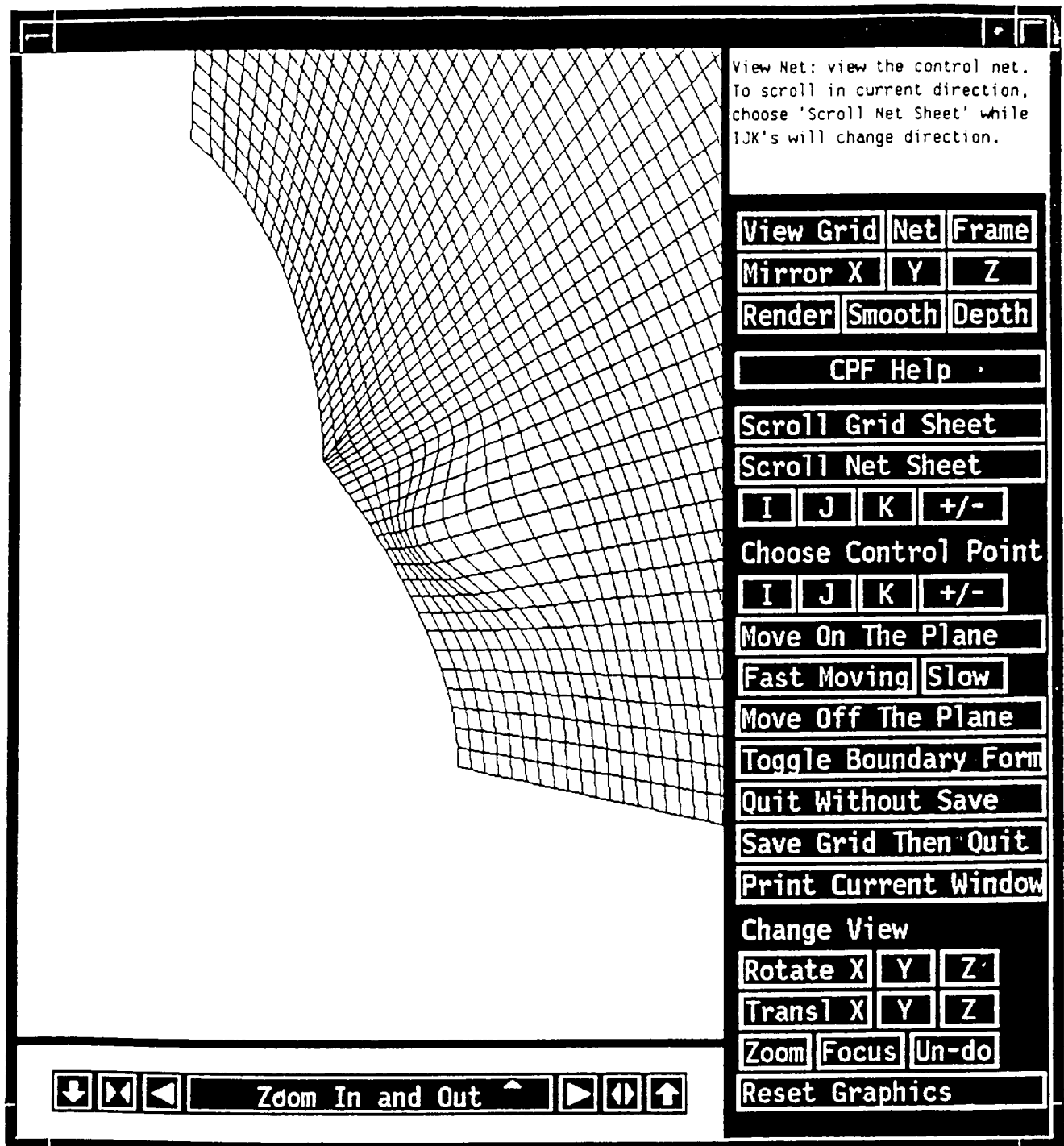
11. For now, we choose Move On the Plane. Here you use your MOUSE to control the movement of that control point on the plane shown. While in this mode, you may click middlemousebutton to change the mapping (you need this if you move your MOUSE horizontally but the control point moves as if vertically). Clicking the rightmousebutton would change the quadrant. If you want to move faster or slower, you must first quit moving by clicking leftmousebutton, then click on the Fast Moving or the Slow button once or more, then choose Move On the Plane to move again.



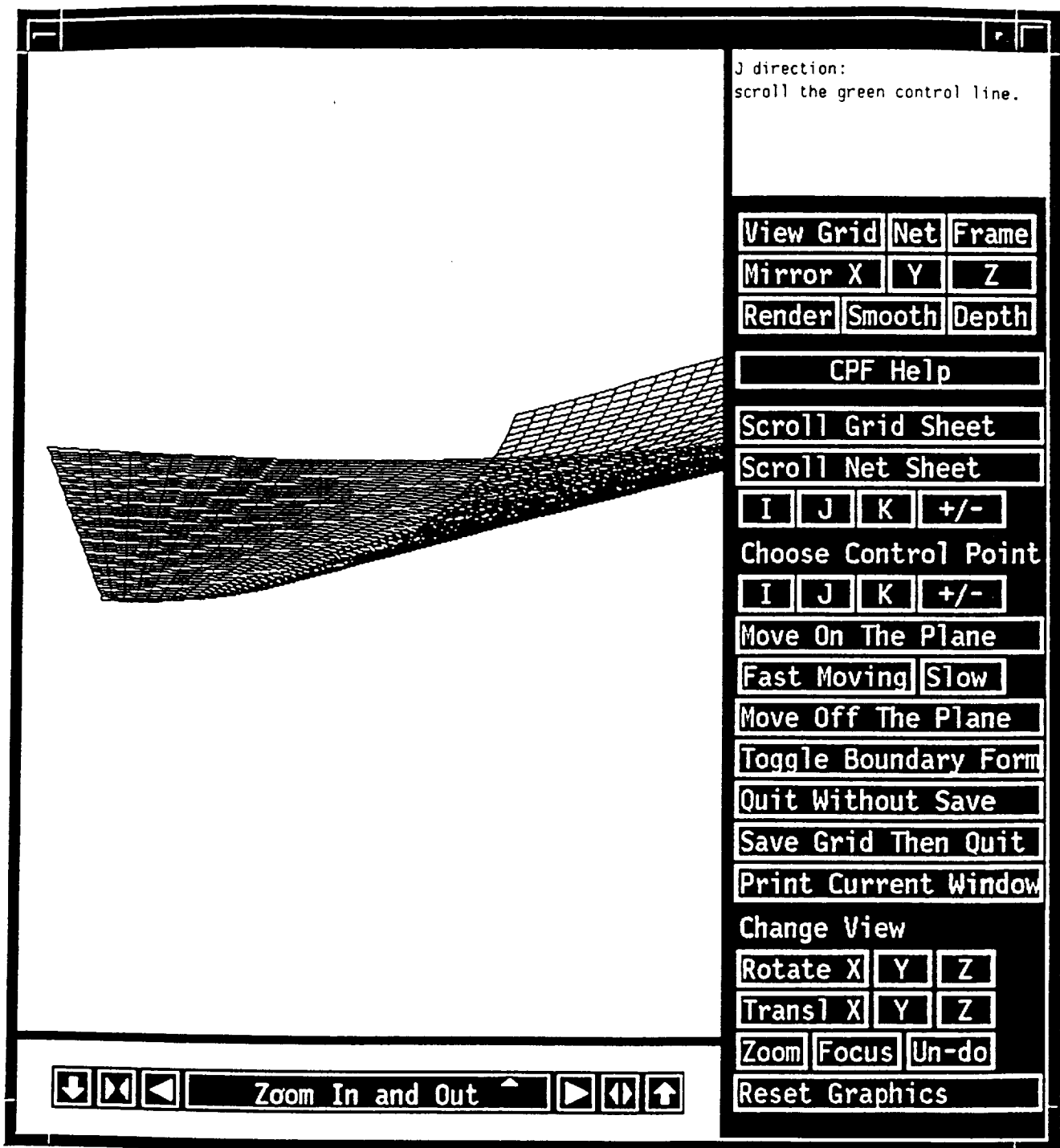
12. We now want to move one more point (on the same control plane). To do so, one would first buttons under Choose Control Point to scroll the thick lines. In this example, we only move thick line in K direction once.



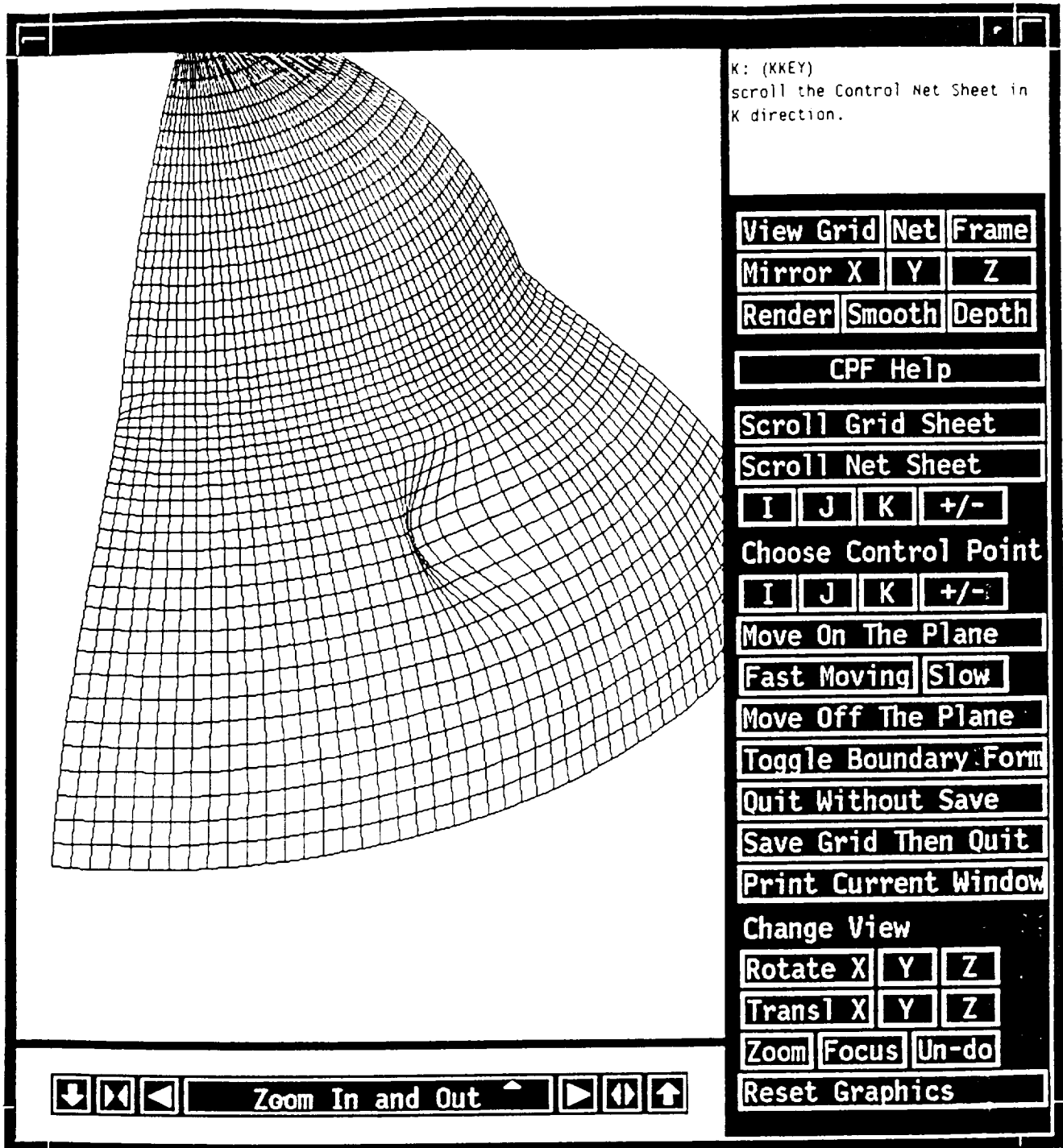
13. We choose Move On the Plane again. Here you use your MOUSE to control the movement of that control point on the plane shown. While in this mode, you may click middlemousebutton to change the mapping (you need this if you move your MOUSE horizontally but the control point moves as if vertically). Clicking the rightmousebutton would change the quadrant. If you want to move faster or slower, you must first quit moving by clicking leftmousebutton, then click on the Fast Moving or the Slow button once or more, then choose Move On the Plane to move again



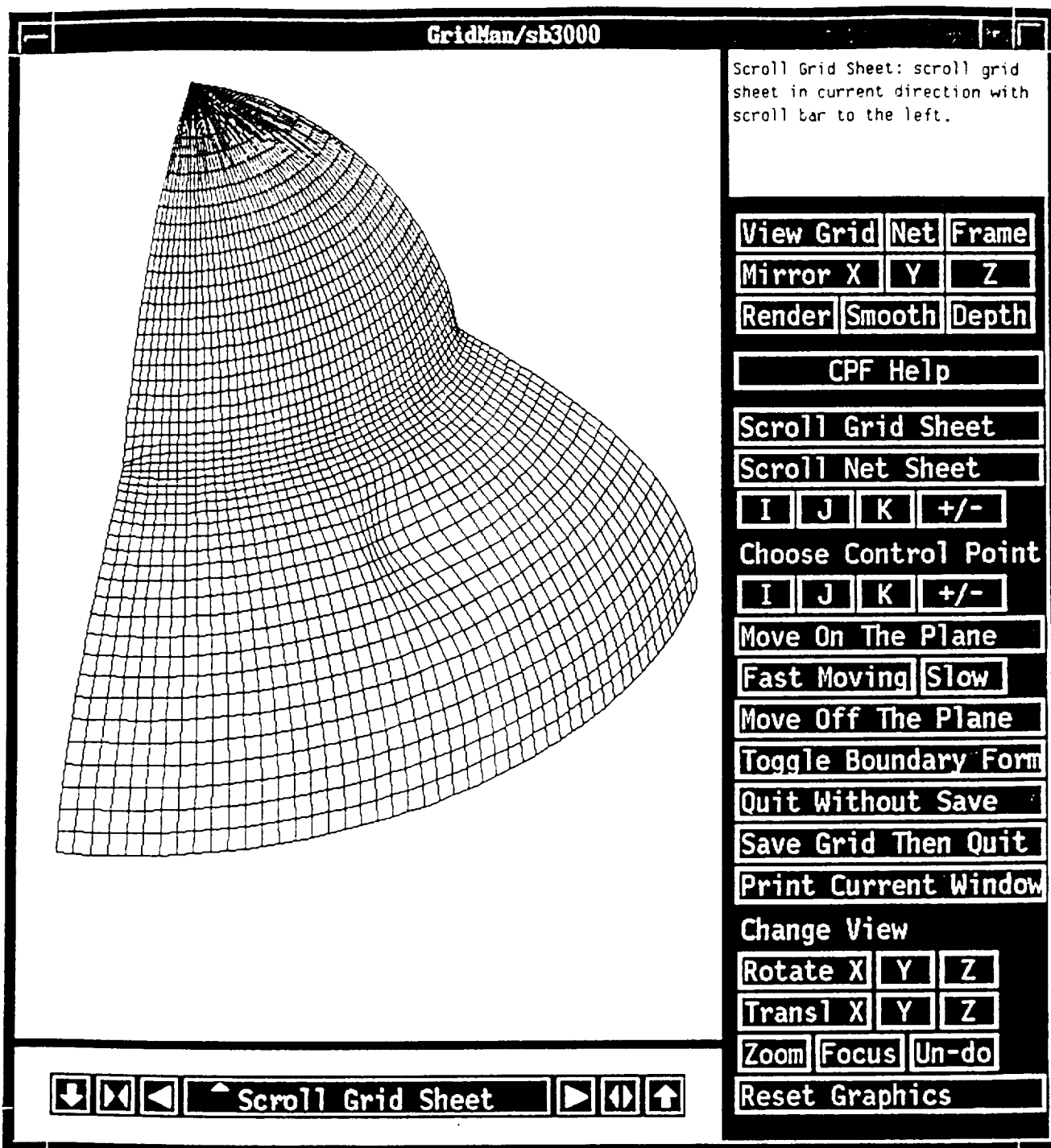
14. We take off the net by clicking on **Net** button to see the grid after we have moved those two control points.



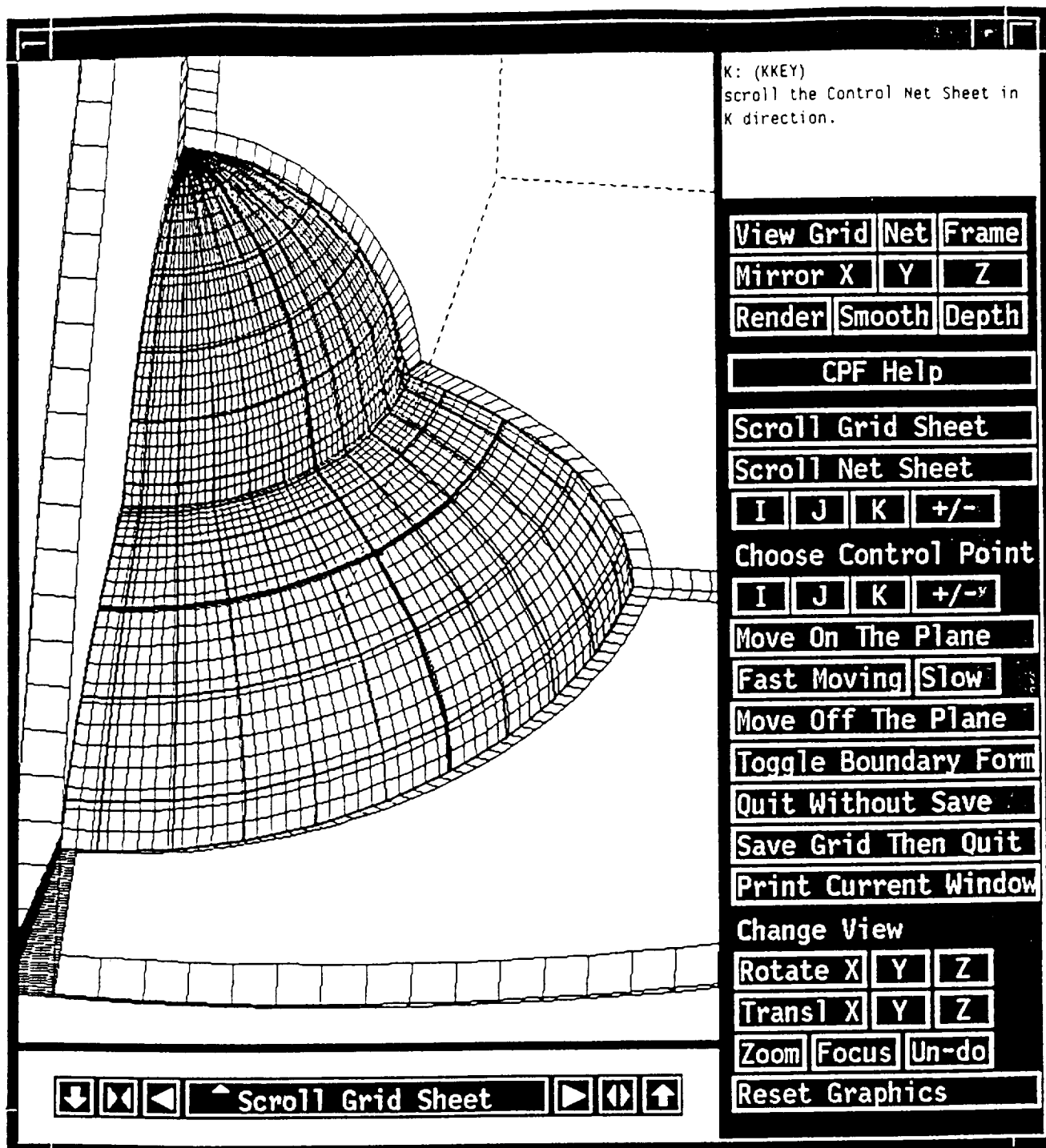
15. Click on **I** button (below Scroll Net Sheet) to view the grid and net in J direction (although net is off).



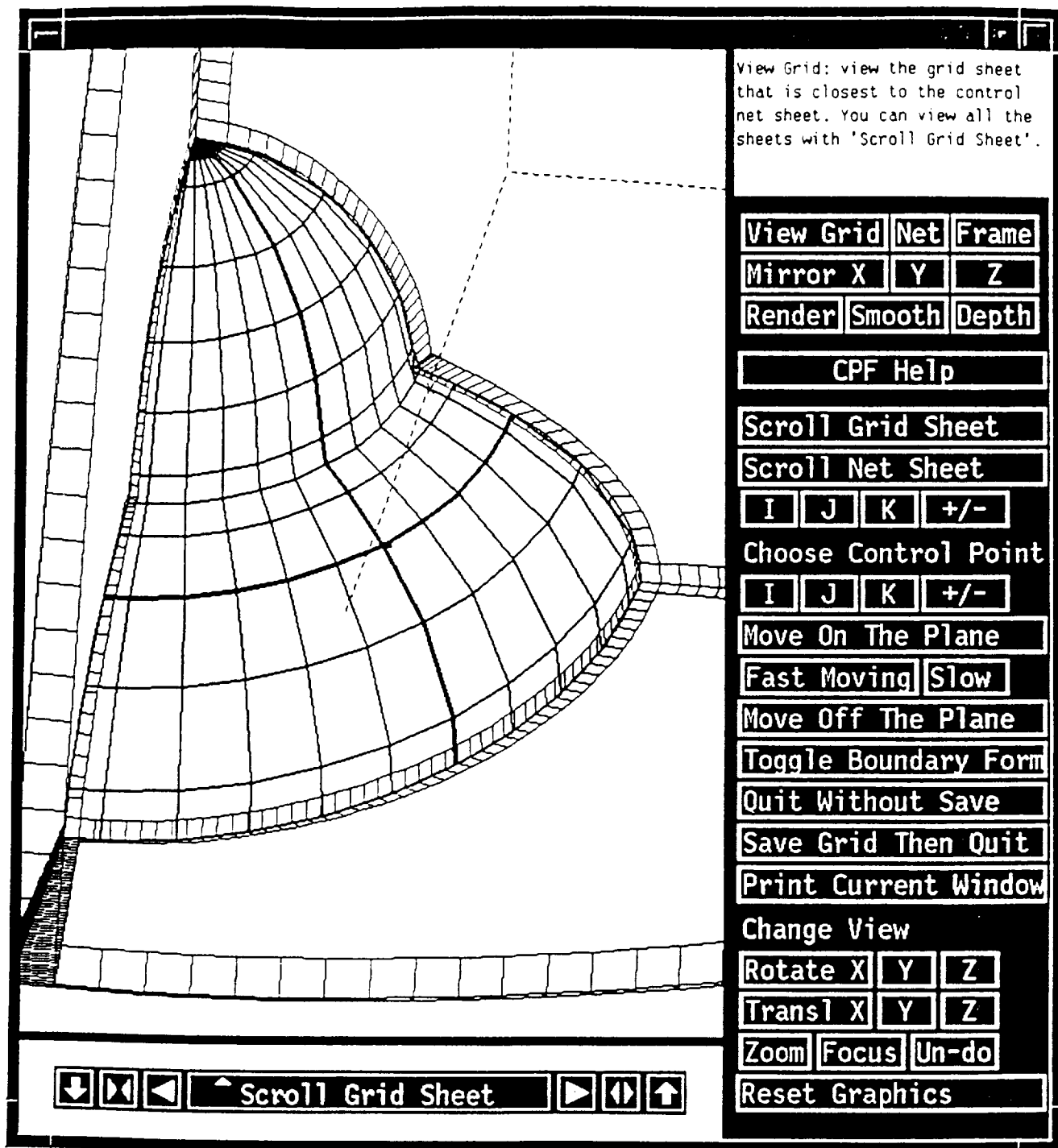
16. Now view the grid in K direction.



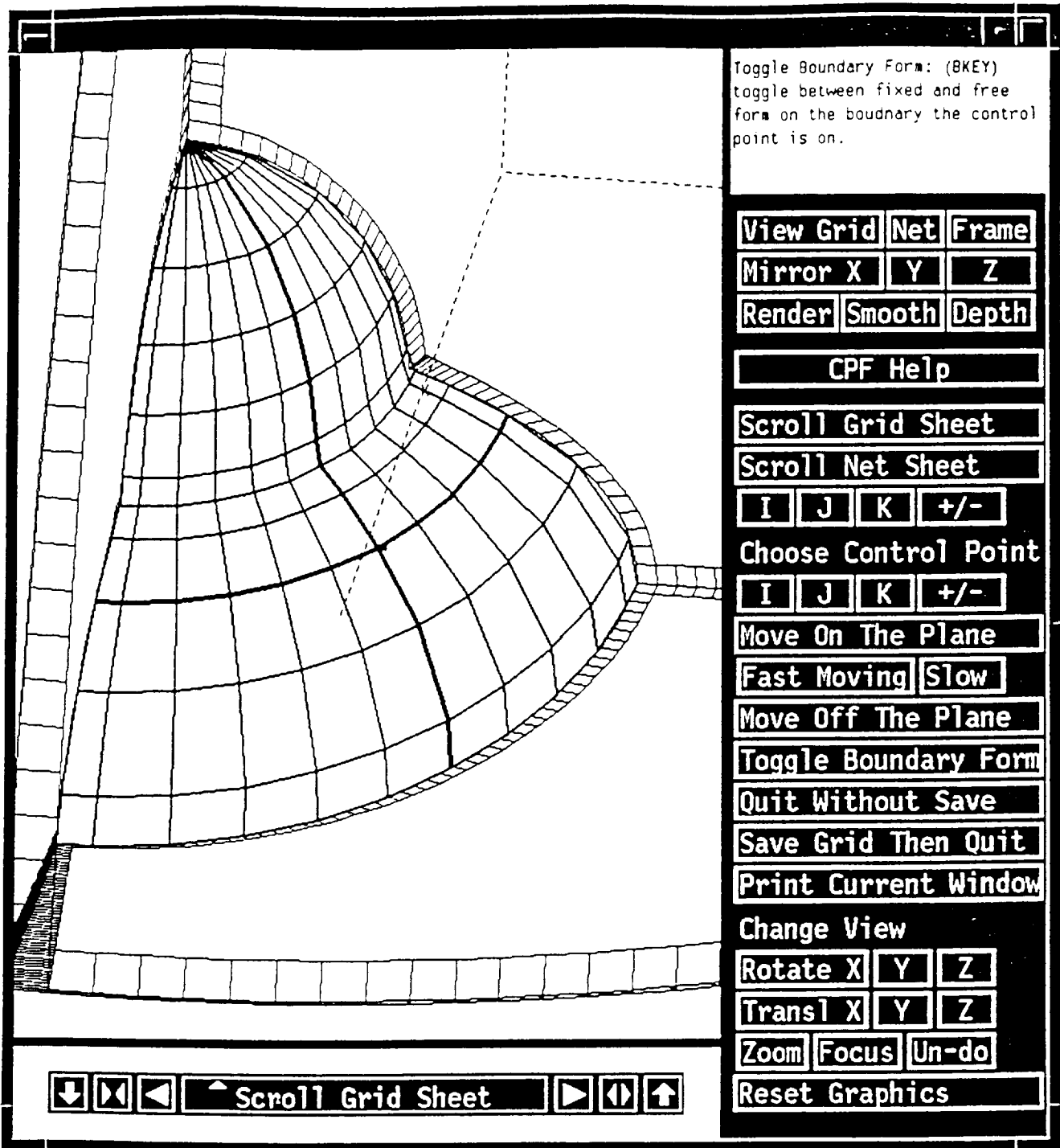
17. To examine grid changes in other sheets, use Scroll Grid Sheet along with the scroll bar. Here, we scroll to a sheet that is below the sheet just shown. As you can see, the changes are smaller.



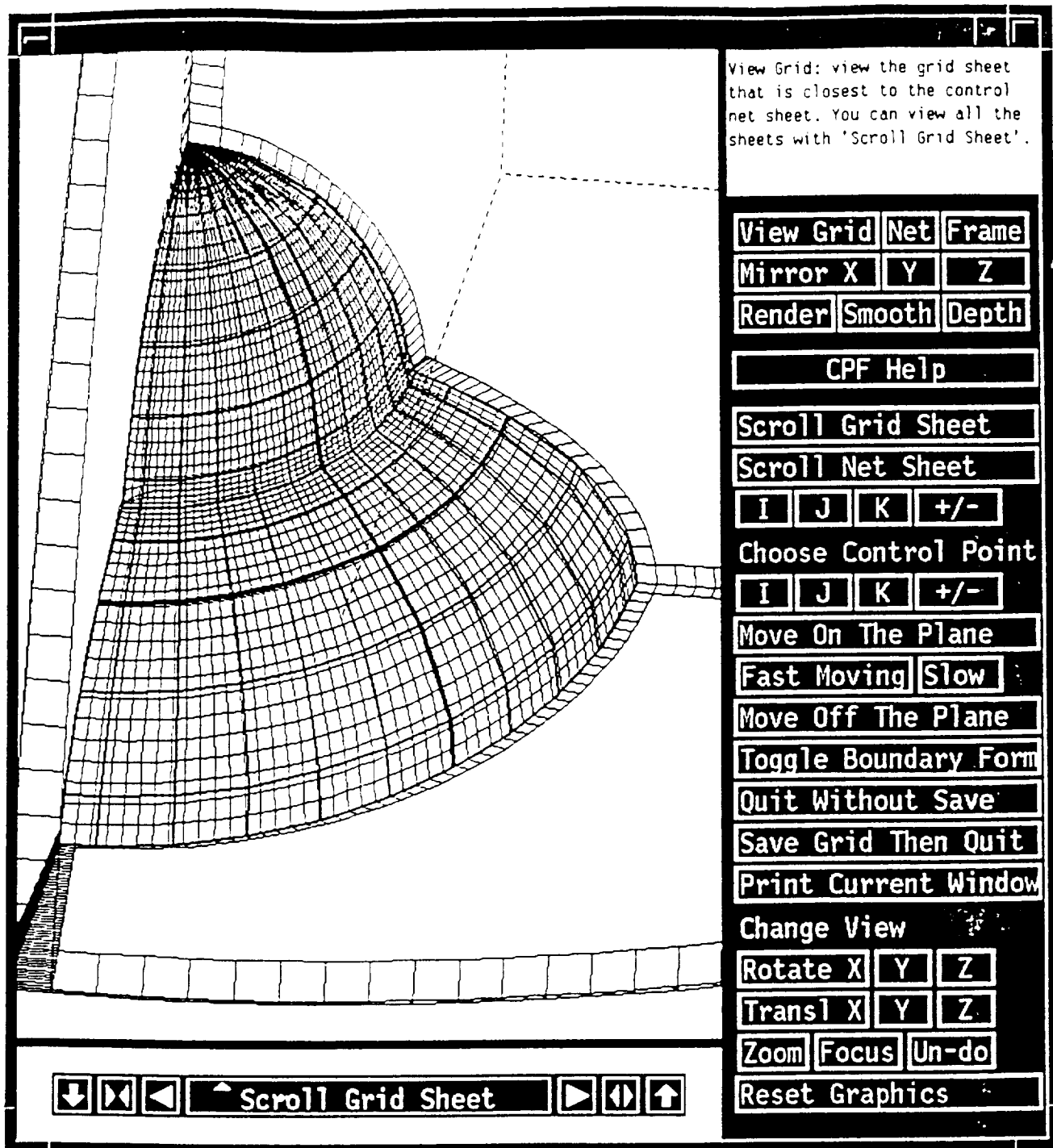
19. We would now like to show the options at the boundary. By clicking on **K** button (below **Scroll Net Sheet**) several times, one again reaches one of the boundary surfaces in K direction.

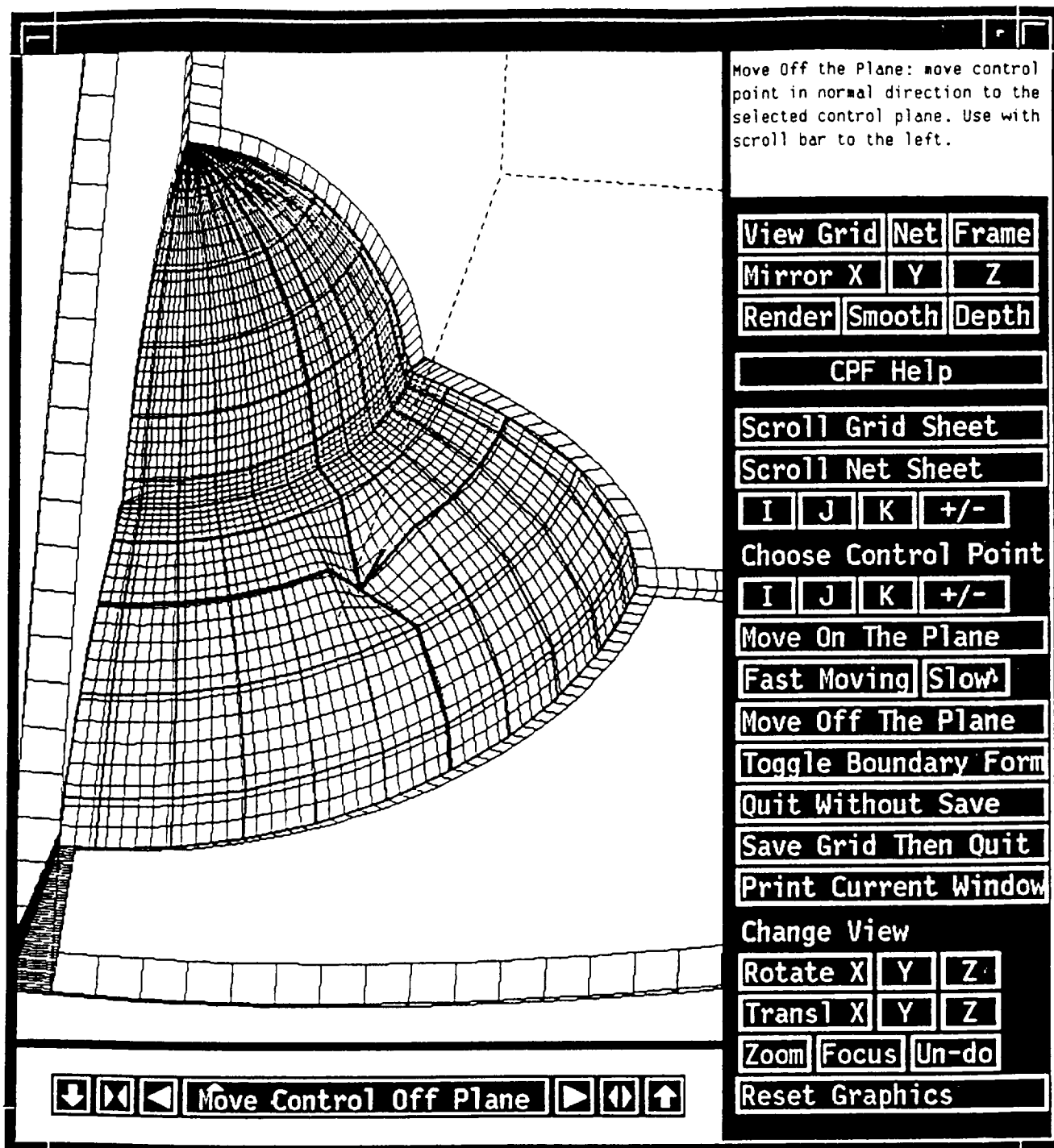


20. Now we toggle off the grid display and begin to examine the frame. You can see first layers of the grid on all 3 boundary surfaces. They not only tell you the grid spacing, but also the boundary type: if you see the first layers, then it is the fixed type. Otherwise it is free form. In this picture, the boundary surface for the K direction is of fixed type.

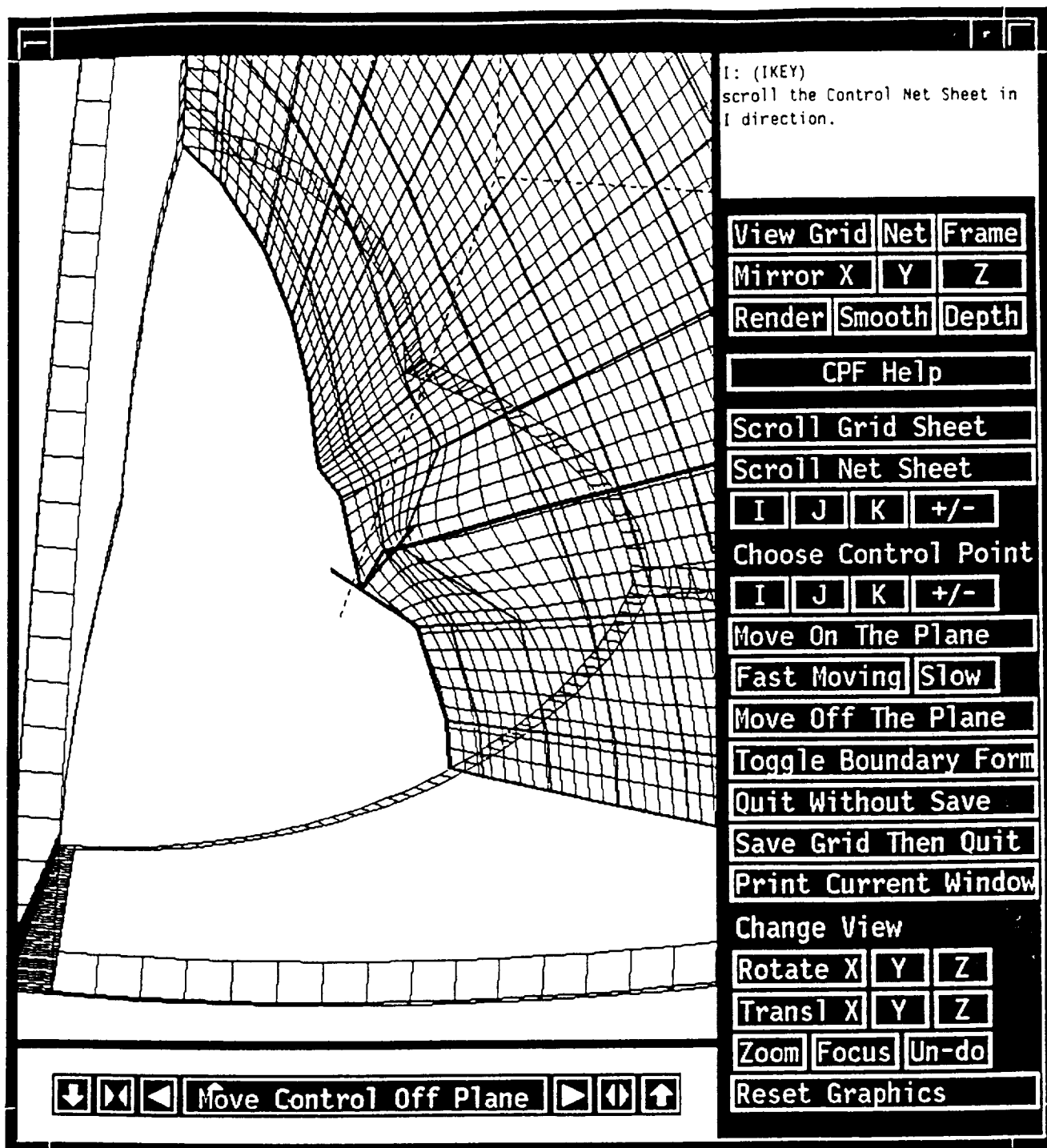


21. Now click on Toggle Boundary Form to change the boundary type (the boundary where the control net is on!). You can see now that the first layers on this boundary are off i.e., it is free boundary now.

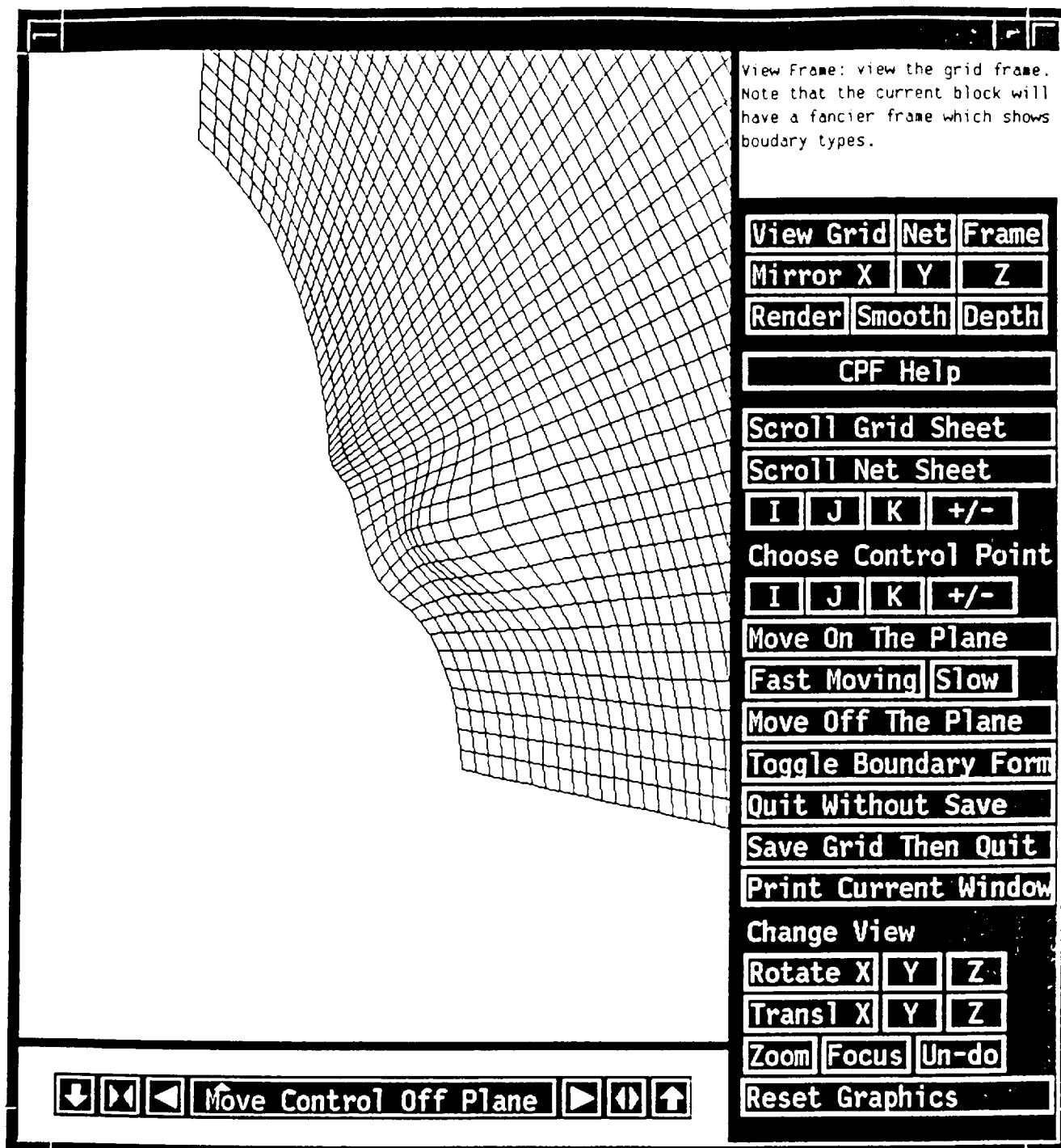




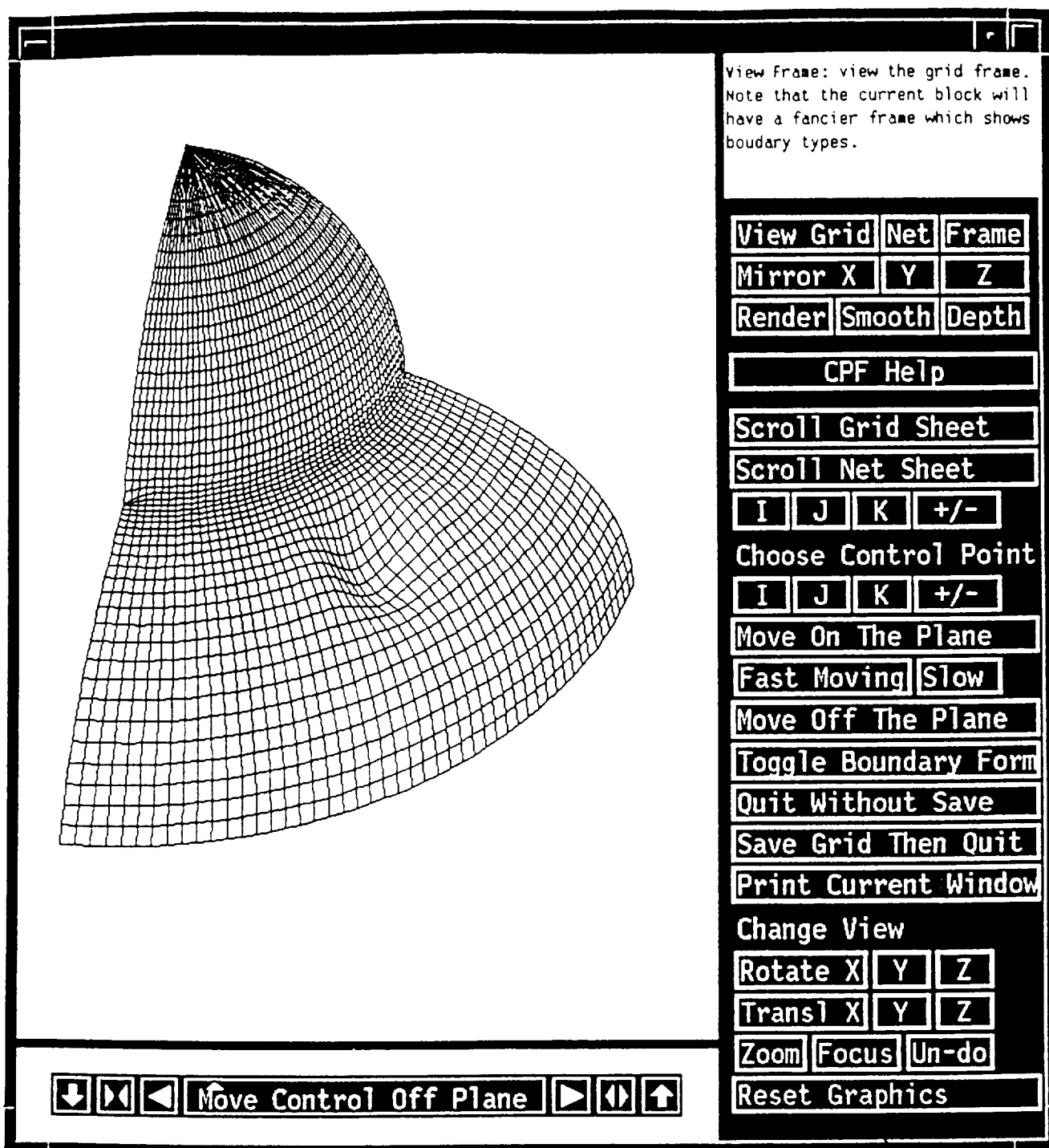
23. We now exercise the Move Off the Plane that will utilize the scroll bar. As you can see, we push the control point inside (remember this surface is free-form now).



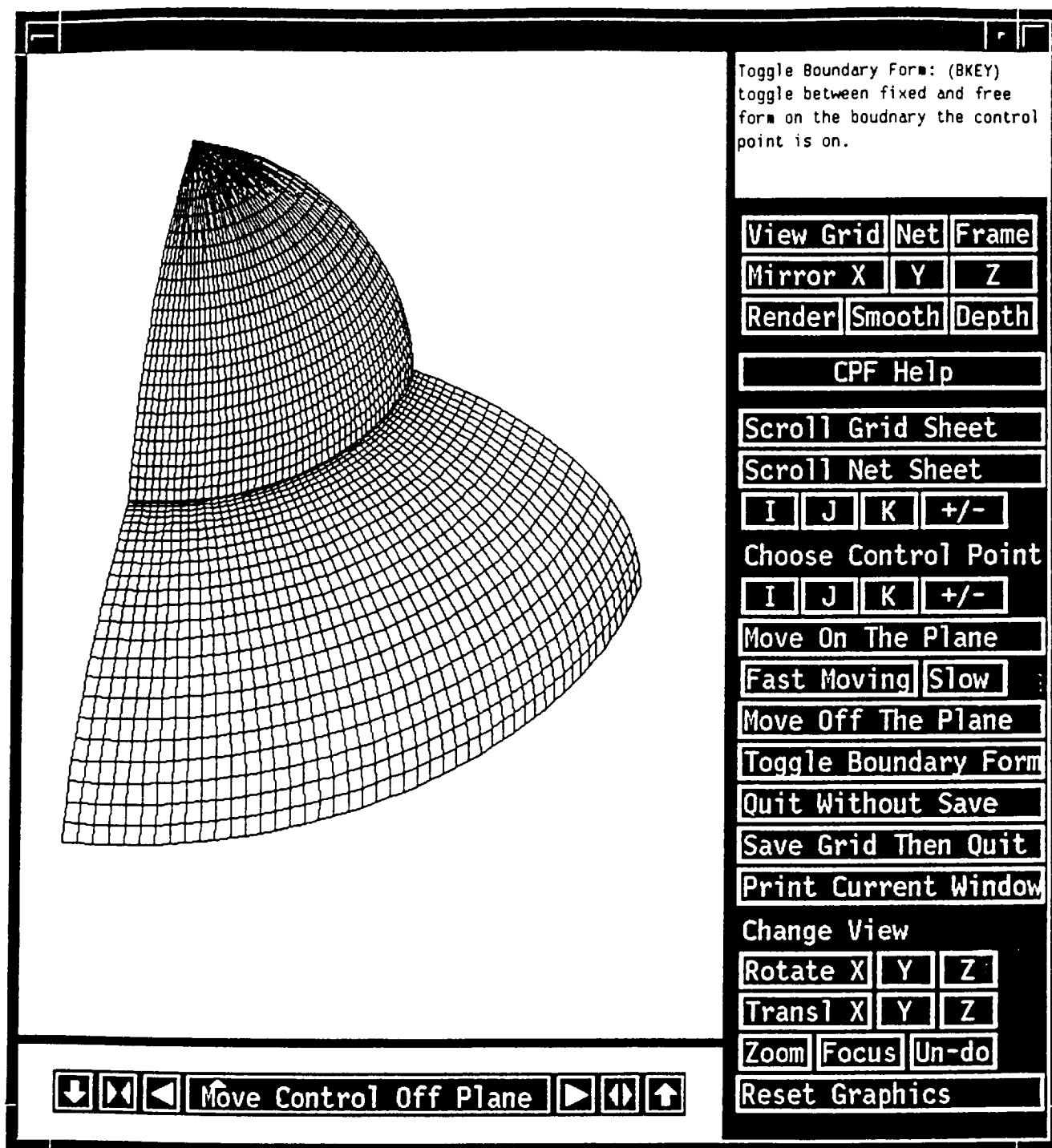
24. View changes in I direction.



25. View grid sheet in I direction only.



26. View grid sheet in K direction only.



27. Click on Toggle Boundary Form again to switch the boundary form back to specified (i.e., fixed type). As you can see, the grid surface is back to the original one.

